THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME LXXVIII SEPTEMBER 1933 NUMBER 2

THE PROBLEM OF CLASSIFYING STELLAR SPECTRA

By O. STRUVE

ABSTRACT

The subdivisions of the Draper classification, intended for statistical investigations with small-dispersion spectrograms, require greater refinement for detailed studies of stellar atmospheres. The first part of this paper deals with the limitations imposed upon such a process of refining by the use of conflicting spectroscopic criteria.

A method is suggested by which discrepancies between criteria may be used to throw light upon physical parameters, other than temperature and pressure, which define the appearance of the spectrum. This method is applied to the B-type stars.

Peculiarities in the intensities of *He* I, *O* II, *Mg* II, etc., are pointed out and discussed.

I

The spectral classification used by Miss Cannon in the *Draper Catalogue* of the Harvard College Observatory represents an empirical system designed to arrange the majority of stellar spectra into a linear sequence. The fact that this was at all possible proves that the more conspicuous differences in the intensities of stellar absorption lines are traceable to one physical parameter, and this we now know to be the temperature of the atmosphere of the star. The Draper classification was adopted by the International Solar Union in 1910, and again, with minor additions, by the International Astronomical Union in 1922. The most important of these additions deals with the effect of pressure or absolute magnitude. A letter "g" is prefixed to the designation of the class if the spectrum exhibits giant properties, and a letter "d" is used to designate dwarfs.

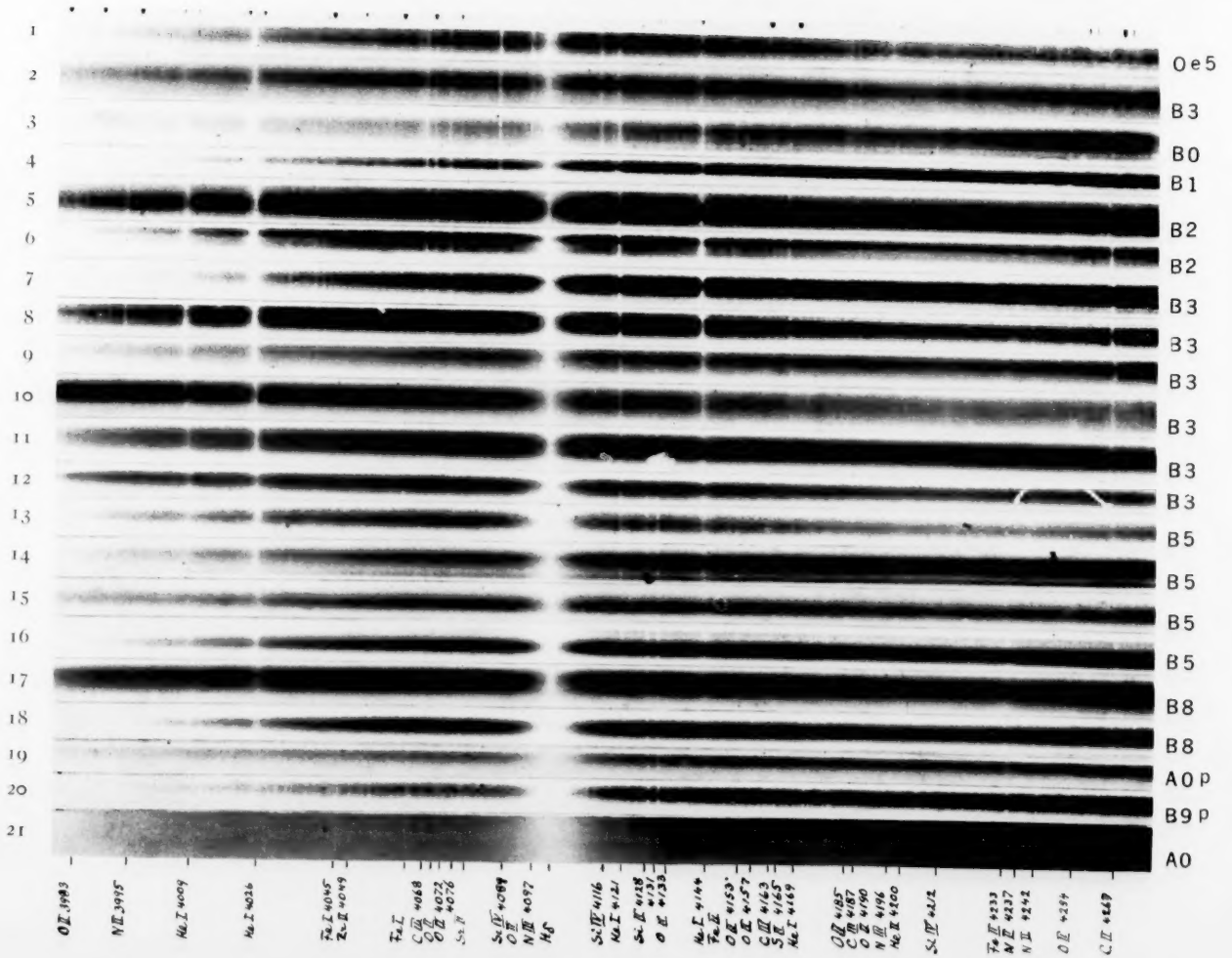
There are other characteristics for which special symbols have been recommended: "e" designates presence of emission lines, "k" stands for interstellar lines; the letters "n" and "s" are probably rough measures of axial rotation.

There remains the question whether a normal stellar spectrum, devoid of emission lines and not suggestive of rapid rotation, is fully defined by the two physical parameters, temperature and pressure. There is no a priori reason to suppose that such should be the case. For example, we do not know whether the relative abundance of different elements is constant for any given values of temperature and pressure. Nor have we any right to assume that the effective depth of a stellar atmosphere does not vary from star to star, unless we are willing to depend upon the treacherous results derived theoretically from star models chosen because they agree, in general, with observation.

If it should be true that the spectrum of a star is fully defined by two physical parameters which can be separated both observationally and theoretically, there would be no reason why the present classification could not be greatly refined by the introduction of a larger number of subdivisions. It should be remembered that the Harvard classification depends upon objective-prism spectrograms, the majority of which have a small linear dispersion. Numerous attempts have been made within recent years to increase the number of spectral subdivisions, and in some cases workers have tried to classify stellar spectra to one-hundredth of a spectral class. The results have been somewhat disappointing: spectral classes assigned at different observatories often differ by several subdivisions, and even at the same observatory contradictory results are sometimes obtained if different criteria are used. Table I is taken from a summary by R. H. Curtiss.[1] It is obvious that the differences in results between observatories greatly exceed possible errors in estimating line intensities. Thus, a difference of seven-tenths of a spectral class between Mount Wilson and Victoria cannot be due to errors in the estimates. It is clearly due to the fact that the criteria were not the same.

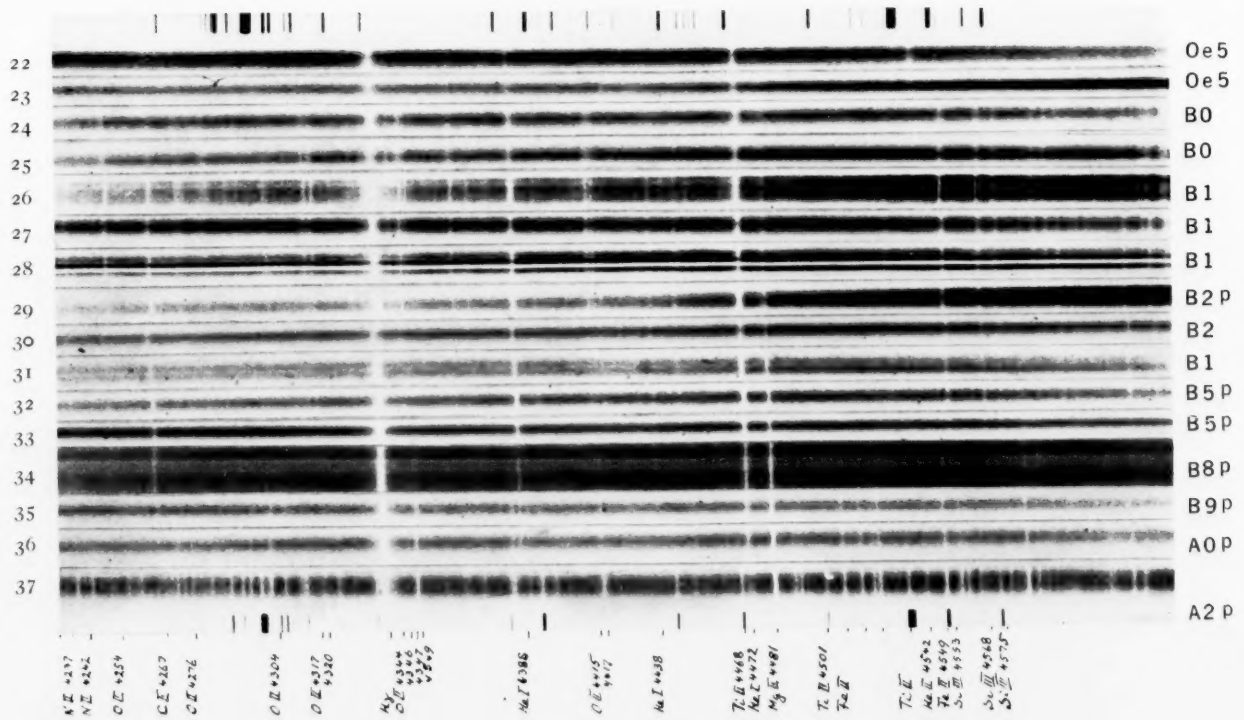
[1] *Handbuch der Astrophysik*, 5, Part I, 100, 1932.

PLATE III



SPECTRA OF B-TYPE DWARFS

PLATE IV

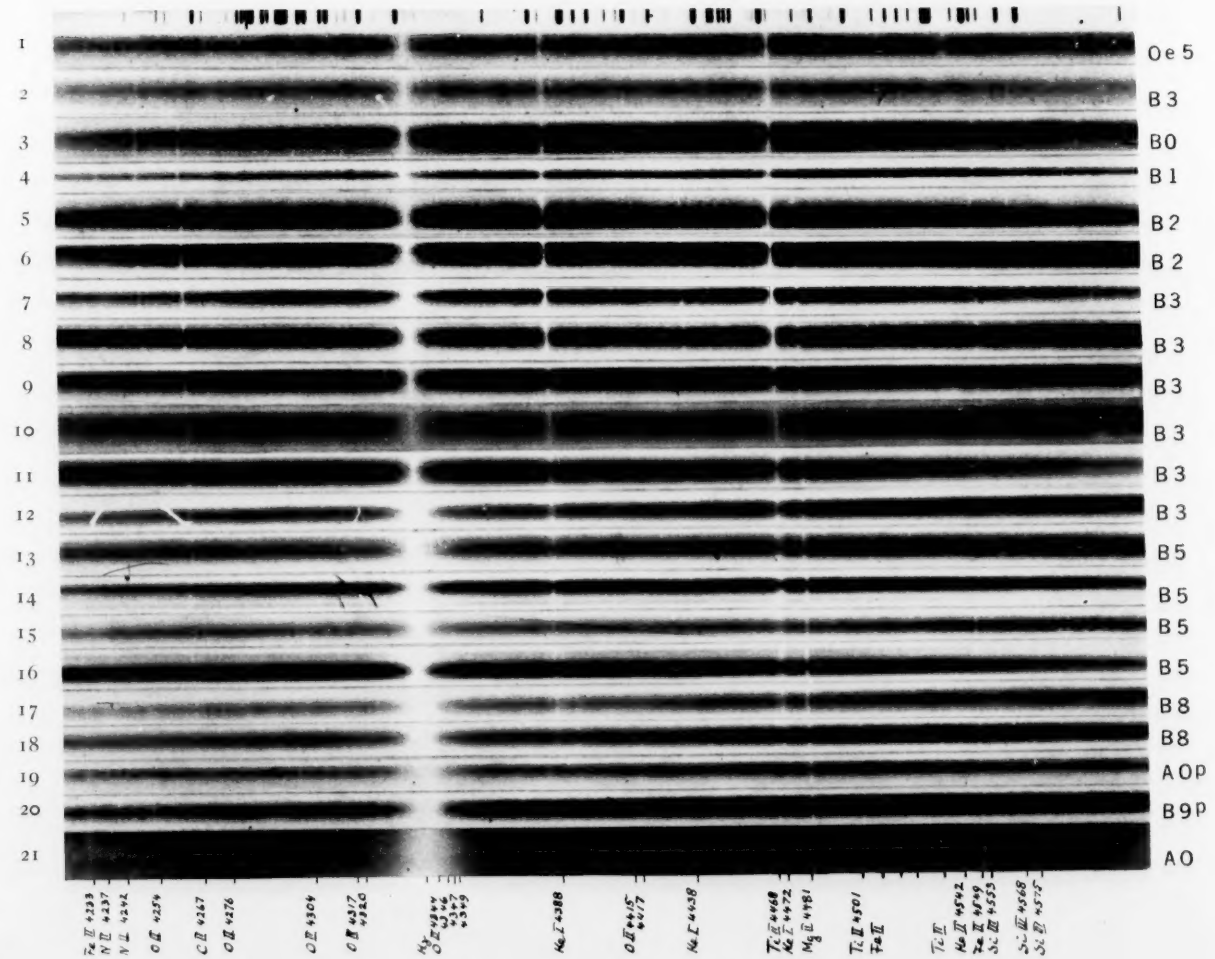


SPECTRA OF B-TYPE GIANTS

UNIV. OF MICH.

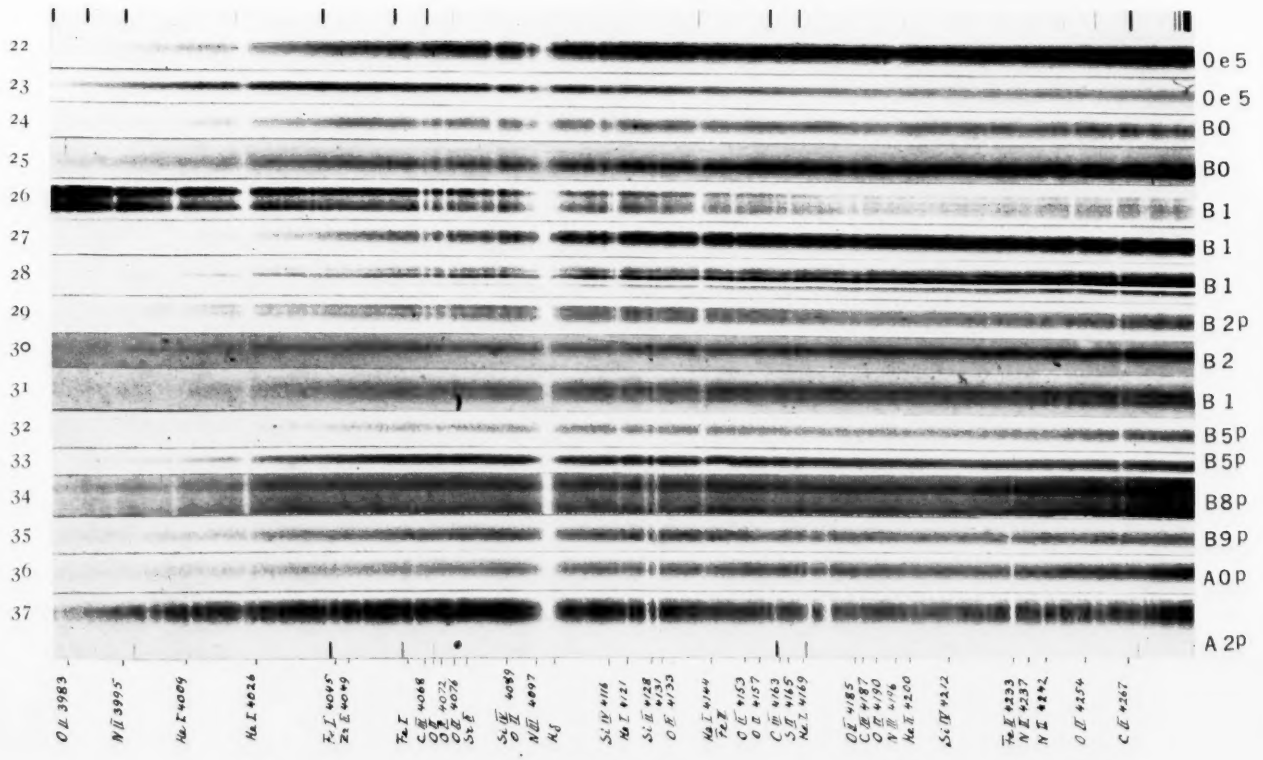
PLATE V

PLATE V



SPECTRA OF B-TYPE DWARFS

PLATE VI



SPECTRA OF B-TYPE GIANTS

UNIV. OF HOUSTON

In order to make progress in the study of stellar spectra it is desirable to investigate a number of questions:

1. If two stars of equal atmospheric temperature and pressure are given, are their spectra necessarily identical? We assume here

TABLE I

Star	Harv. Vis. Mag.	Mt. W. Abs. Mag.	Vict. Abs. Mag.	Harv. Class	Mt. W. Est.	Mt. W. Meas.	Vict. Class	Mich. Class
β Cr. B.	3.7	−0.3	−0.4 −0.2	Fop	F2	F4	F2	F3.2
ν Her.	4.5	−0.2	+1.2 +1.5	Fo	F2p	F3	F3	F3.5
20 C. Vn.	4.7	−1.4	+0.7 +1.0	Fo	F4	F3	F3	F4.1
ϵ Aur.	3.4	−2.0	−2.9 −2.7	F5p	F5p	F9	F2	F3.4
β Dra.	3.0	−3.5	−2.1 −1.5	Go	Gop	F8	F9	F9.0
29 Mon.	4.4	−4.2	−2.1 −2.5	Go	G3p	F9	Go	F8.5
ϵ Leo	3.1	−0.9	.....	Gop	Go	Go	.....	Go.1
ϵ U. Mi.	4.4	−1.4	.....	G5	G2	G2	.....	G2.6
o U. Ma.	4.5	−0.8	.....	Go	G2	G2	.....	G2.5
η Her.	3.6	+0.9	+1.1 +1.0	Ko	G5	G5	G6	G5.6
ϵ Vir.	3.0	0.0	+1.4 +1.4	Ko	G6	G6	G6	G5.0
β Her.	2.8	−1.0	+0.7 +1.0	Ko	G5	G6	G5	G5.1
ϵ Boo.	2.7	−0.9	+0.5 +1.0	Ko	G8	G7	G6	G6.3

that the stars show no rotational broadening, and are not complicated by emission lines, etc.

2. If the answer to the preceding question should be negative, we shall have proved that pressure and temperature are insufficient to characterize the spectra. One or more additional physical param-

eters would be needed, and an effort should be made to discover these.

3. It is possible that among stars of certain classes the two principal parameters are sufficient, while in other classes they are not.

4. The intensity of an absorption line depends upon the number of absorbing atoms, and this in turn depends upon (*a*) effective thickness of absorbing layer, (*b*) density of atoms in the lower energy state of the line, (*c*) absorption coefficient of the given line. The first factor is believed to be dominated by the general opacity of the stellar atmosphere. The second represents the combined effect of temperature, pressure, and abundance. The third involves the probability that the line will be absorbed.

It seems impossible to predict the theoretical intensity of a stellar absorption line. In his recent work Milne has obtained widely differing results depending upon assumptions which might be considered equally plausible. Under these circumstances it is desirable to proceed by purely observational methods, in order not to be biased by theoretical results which still rest on uncertain foundations. By doing so we shall be able to provide a satisfactory basis for future theoretical investigations.

In the next section I shall discuss more particularly the classification of the B-type stars. The A's have been studied at the Yerkes Observatory by W. W. Morgan, and the F's are now under investigation by J. A. Hynek.

II

The spectral classification of stars of classes O, B, A, and F has remained in a somewhat unsatisfactory state because of the great variety in the character (or in the width) of the absorption lines. Shajn, Elvey, and I have shown that these differences may be satisfactorily interpreted as an effect of rapid axial rotation. A statistical study of rotational velocities has been made by Miss Westgate.[2] Since it is technically difficult, if not impossible, to compare a star having wide lines with one having narrow lines, I have limited this

[2] *Astrophysical Journal*, **77**, 141, 1933; **78**, 46, 1933.

discussion to spectra having narrow lines. Whether or not by doing so we obtain a physically homogeneous group is not certain. Narrow lines indicate one of two things: either the velocity of rotation is small or the axis of the star nearly coincides with the line of sight. We do not yet know whether the spectra of these two groups of stars are identical.

I have shown elsewhere how we may divide the B stars into three groups:[3] giants, intermediate stars, and dwarfs. I have now selected only the stars for which good spectrograms on Eastman Process emulsion were available, and have divided them into two groups: giants and dwarfs. The criteria were: (*a*) absence or presence of hydrogen wings, (*b*) intensity of forbidden helium lines, (*c*) intensity of the interstellar calcium line K. Criteria (*a*) and (*b*) are directly related to pressure, so that our division is essentially independent of any other physical parameters.

Table II gives the stars, 30 dwarfs and 17 giants. The details have been taken from Schlesinger's *B.S. Catalogue*. Plates III, IV, V, and VI contain reproductions of some of the spectra. In each of the two groups I have arranged the stars, as nearly as was possible, in order of decreasing temperature.

An inspection of the plates reveals many interesting details which are either entirely new or which, though known for some time, have not been carefully investigated and explained. We shall discuss these below.

1. In the later types there is a wide gap between giants and dwarfs. Does a similar gap exist in the B stars, or do they merely show a measurable amount of dispersion in atmospheric pressure? The fact that in an earlier paper[3] I subdivided the stars into giants, average stars, and dwarfs might indicate that the latter is true. However, I have now found, with somewhat better material, that it is possible in almost every case to assign a star to either the giants or the dwarfs. There are few intermediate cases; possibly β Canis Majoris, ϕ Herculis, η Leonis, and 4 Lacertae should be called intermediate. I am now inclined to think, on spectroscopic evidence alone,

[3] *Ibid.*, **74**, 225, 1931.

TABLE II

Name	No. in Plates	α	δ	Mag.	Spec.	Proper Motion α	Proper Motion δ	Par.	Rad. Vel. in Km	Remarks
				Giants						
1. 39 λ Ori	22	$5^h29^m38^s$	+ 9° 52′	3.66 5.56	Oe5	+.004	−.011	+.006	+35 Var.	4″, 45°, fixed $v_0=+35$ km
2. 19 Cep	23	22 2 4	+61 48	5.17	Oe5	+.013	−.003	.003	Var.	$v_0=-13$ km
3. 53 κ Ori	24	5 43 1	− 9 42	2.20	Bo	+.007	−.005	.013	+20	
4. 47 ρ Leo	.....	10 27 33	+ 9 49	3.85	Bop	−.004	−.004	.012	+41	
5. 15 κ Cas	25	0 27 19	+62 23	4.24	Bo	+.012	−.001	.002	Var.	$v_0=-7$ km
6. 2 β C. Ma	26	6 18 18	−17 54	1.99	B1	−.003	.000	.012	Var.	$v_0=+33$ km
7. 44 ζ Per	27	3 47 51	+31 35	2.91	B1	+.015	−.018	.006	+20	9.3M, 13″, 208°, c.p.m.
8. 21 ε C. Ma	28	6 54 42	−28 50	1.63	B1	+.005	.000	.012	+28	9M, 8″, 160°, fixed
9. 9 Cep	29	21 35 14	+61 38	4.87	B2p	+.008	.000	.003	−15	
10. 55 Cyg	30	20 45 32	+45 45	4.89	B2	+.006	−.006	.006	Var.	
11. 25 χ Aur	31	5 26 13	+32 7	4.88	B1	+.008	−.016	.004	Var.	655 days, $v_0=+4$ km
12. 24 o^2 C. Ma	32	6 58 51	−23 41	3.12	B5p	−.003	−.005	.007	Var.	24.3 days, $v_0=+49$ km
13. 67 Oph	33	17 55 38	+ 2 56	3.92	B5p	+.004	−.014	.006	−3	8M, 55″, 142°, fixed
14. 19 β Ori	34	5 9 44	− 8 19	0.34	B8p	+.005	−.002	.006	Var.	7M, 0″, 201°, fixed
15. 2 Hev Cam	35	3 20 58	+59 36	4.42	B9p	+.004	−.002	.009	−5	9.0M, 2″.4, 160°
16. 67 σ Cyg	36	21 13 29	+38 59	4.28	Aop	−.001	−.008	−.007	Var.	11.0 days, $v_0=-2$ km
17. 50 α Cyg	37	20 38 1	+44 55	1.33	A2p	+.004	−.002	−.005	Var.	Deneb, $v_0=-4$ km

TABLE II—*Continued*

Name	No. in Plates	α	δ	Mag.	Spec.	Proper Motion α	Proper Motion δ	Par.	Rad. Vel. in Km	Remarks
					Dwarfs					
1. 10 Lac	1	$22^h34^m46^s$	$+38°32'$	4.91	Oe5	+.003	−.011	.....	Var.	$v_0=-9$ km
2. 36 ν Ori	2	5 27 6	− 7 23	4.64	B3	+.007	−.012	+.004	+18	
3. 37 ϕ Ori	.....	5 29 20	+ 9 25	4.53	Bo	+.002	−.008	.003	Var.	8.4 years, $v_0=+32$ km
4. 23 τ Sco	3	16 29 39	−28 1	2.91	Bo	−.009	−.036	.007	o	
5. 6 λ Lep	.....	5 14 58	−13 17	4.29	B1	+.004	+.003	.005	+20	
6. 8 β Cep	4	21 27 22	+70 7	3.32	B1	+.013	+.003	.008	Var.	8M, 14″, 250°, fixed
7. 48 ν Eri	.....	4 31 19	− 3 33	4.12	B2	+.003	−.003	.005	Var.	0.19 days
8. 82 δ Cet	5	2 34 21	− o 6	4.04	B2	+.013	+.001	.005	Var.	$v_0=+11$ km
9. 88 γ Peg	6	o 8 5	+14 38	2.87	B2	+.003	−.015	.010	+5	Algenib
10. 102 Her	7	18 4 29	+20 48	4.32	B3	+.003	−.017	.005	Var.	$v_0=-14$ km
11. 17 ζ Cas	8	o 31 24	+53 21	3.72	B3	+.023	−.011	.005	+3	Vel. perhaps var.
12. 42 θ Oph	.....	17 15 52	−24 54	3.37	B3	+.001	−.031	.009	Var.	0.29 days
13. 20 η Lyr	9	19 10 21	+38 58	4.46	B3	+.004	−.004	.004	Var.	8M, 28″, 82°, fixed
14. 85 ι Her	10	17 36 38	+46 4	3.79	B3	−.004	−.002	.007	−18	Vel. possibly var.
15. 45 ϵ Cas	11	1 47 12	+63 11	3.44	B3	+.039	−.019	.013	− 7	
16. 29 π And	12	o 31 32	+33 10	4.44	B3	+.023	−.011	.008	Var.	8.5M, 36″, 173°, c.p.m.
17. 2 ϵ Del	13	20 28 26	+10 58	3.98	B5	+.012	−.027	.009	Var.	$v_0=-19$ km
18. 22 τ Her	14	16 16 44	+46 33	3.91	B5	−.008	+.031	.011	−14	14M, 7″, 147°, c.p.m.
19. 20 c Tau	15	3 39 52	+24 4	4.02	B5	+.031	−.046	.013	+8	Maia
20. 22 ζ Dra	16	17 8 30	+65 50	3.22	B5	−.010	+.021	.026	−14	
21. 112 β Tau	17	5 19 58	+28 31	1.78	B8	+.034	−.177	.035	+10	
22. 4 γ Crv	18	12 10 40	−16 59	2.78	B8	−.158	+.013	.021	Var.	$v_0=-4$ km
23. 4 Lac	.....	22 20 28	+48 58	4.64	B8p	−.005	−.013	.007	−26	
24. 11 α Dra	19	14 1 41	+64 51	3.64	Aop	−.049	+.017	.023	Var.	51.4 days, $v_0=-15$ km
25. α Lyr	21	18 33 33	+38 41	0.14	Ao	+.209	+.278	.123	−14	Vega
26. α And	.....	o 3 13	+28 32	2.15	Aop	+.143	−.163	.040	Var.	96.7 days, $v_0=-11$ km
27. 11 ϕ Her	20	16 5 37	+45 12	4.26	Bop	−.018	+.024	.015	−16	
28. τ^9 Eri	.....	3 55 40	−24 18	4.69	Aop	+.012	+.003	.012	Var.	$v_0=+24$ km
29. 30 η Leo	.....	10 1 53	+17 15	3.58	Aop	+.002	−.010	.....	+ 2	
30. 13 Mon	.....	6 27 30	+ 7 24	4.50	Aop	+.006	−.010	.007	+12	

that there are two fairly distinct groups of stars having different atmospheric pressures.[4] The ratio

$$\frac{\text{dwarfs}}{\text{giants}} = \frac{30}{17} \approx \frac{2}{1}$$

is somewhat affected by selection: I have included wider lines among the giants than among the dwarfs. It is also possible that slow rotation is more frequent among the giants than among the dwarfs. The real ratio may therefore easily be 3/1 or even 4/1. This result would agree well with that derived statistically by G. Strömberg.[5]

2. The arrangement of the stars within each group is according to decreasing temperature. In general, it is possible to assign to each star a definite place in the sequence. The Harvard spectral classes appear on the right-hand margin of the plates. They show some scatter, owing to the difficulty of classifying stars on small-scale objective-prism plates, but on the whole they agree with my arrangement. It is obvious, however, that a much finer classification than that of the *Draper Catalogue* is possible. Thus, among the dwarfs, Harvard class B3 includes spectra which are widely different in the intensities of the *Si* III lines, which range from fairly strong in 102 Herculis to complete invisibility in 29 π Andromedae. A similar variation is shown by the *O* II lines 4415, 4417. The rapid decrease in intensity of *Si* IV 4116 from B1 to B2 among the dwarfs is noteworthy. Among the giants *He* II 4542 shows greatly differing intensities in Oe5. The unidentified line at 4420 shows considerable variations in intensity for the three B1 giants; it is exceedingly faint in ϵ Canis Majoris. These examples prove that the definition now obtainable on single-prism spectrograms is sufficient to classify the B stars to approximately one-twentieth of the interval from O9 to A0.

3. The preceding result raises another question: Is the refinement of spectral classification limited merely by the definition of the

[4] Miss E. T. R. Williams has shown (*ibid.*, **75**, 386, 1932) that my giants, intermediate stars, and dwarfs have markedly different absolute magnitudes. I am inclined to think, however, that the "intermediate" stars are, with a few exceptions, a mixture of giants and dwarfs which could not be properly classified on the plates then available. Among the later B's and the A's this division is not so pronounced.

[5] *Ibid.*, **74**, 342, 1931.

plates and by our inability to estimate or measure small differences in line intensity? The answer is negative. If care is taken in making the estimates, it becomes apparent that our two groups of stars, the giants and the dwarfs, do not represent linear sequences. Consider, for example, the dwarf star 20 c Tauri (Maia). The helium lines 4472 and 4388 are distinctly too weak for the place assigned to this star in our scheme. Moving it downward to a place between γ Corvi and α Draconis would remedy this, but it would leave *Mg* II 4481 in the wrong place. This line is weaker in 20 c Tauri than in several stars preceding it in our sequence, which would suggest that it should be moved upward among the B_3 stars. There is a discrepancy in the classification, depending upon which of two criteria is used.

This discrepancy is not caused by small differences in atmospheric pressure, because the wings of the hydrogen lines definitely place Maia among the dwarfs. While both *He* I and *Mg* II are too weak for the place assigned to this star, *Fe* II 4549 and 4233 are rather strong, while *C* II 4267 is slightly too weak, and *Si* II 4128 and 4130 are about normal.

Neither temperature nor pressure explains these facts. We are therefore forced to admit the existence of other physical parameters which control the appearance of a spectrum. Three simple hypotheses suggest themselves: (*a*) the effective depth of a stellar atmosphere may not be fully defined by pressure and temperature, as has been assumed in all earlier work; (*b*) the relative abundance of different elements may not be the same in all stars; (*c*) the tendency toward the formation of emission lines, which is pronounced in the brighter members of the Pleiades, may affect the appearance of the absorption lines.

Hypothesis (*a*) is ruled out because *He* I and *Mg* II would demand a small depth of atmosphere, while *Fe* II would require normal depth.

Hypothesis (*b*) may be considered in the light of Russell's recent theoretical results on the opacity of stellar atmospheres.[6] Great abundance of hydrogen in any given star would increase the opacity and reduce the intensities of all other lines. In Maia this is contrary to observation.[7] There remains the possibility that *He* and *Mg* are

[6] *Publications of the American Astronomical Society*, **7**, 99, 1932.

[7] However, Russell has shown that the effect may be traced in certain stars.

less abundant than usual, while the abundance of *Fe* II is normal or even greater than normal. The hydrogen lines seem to be normal.

Hypothesis (*c*) is improbable; a tendency to form emission lines might be expected to cut down the intensity of *H* and of *He*. If this were so, 20 c Tauri would have to be moved to the hotter stars. But this is contrary to the strength of the *Fe* II lines.

Whether such discrepancies are frequent is difficult to say. I have the impression that they are more pronounced among the later subdivisions of class B, and the work of Morgan[8] would indicate that they are even more pronounced among the A stars. His suggested division into two parallel spectral branches can, of course, be interpreted in a manner similar to that used in this section.

We may conclude that pressure and temperature are not sufficient to describe a stellar absorption-line spectrum, and the investigation of small discrepancies similar to those observed in 20 c Tauri promises to throw light upon new physical parameters such as abundance of elements, etc.

4. The behavior of *He*-triplets and *He*-singlets has been discussed in my paper on B stars.[9] It is now possible to confirm and expand these results. Comparing triplets 4472 and 4026 with singlets 4388 and 4009, we notice that with increasing temperature the singlets fade out more rapidly in the giants than in the dwarfs. For the cooler stars there is little if any difference in the ratio triplet/singlet between giants and dwarfs. Maximum intensity occurs at about B2 for both the triplets and the singlets.

If the Harvard classes are retained as corrected by my sequences, there is a null effect in the intensities of *He* I for the hottest stars. At and near maximum (B2) and past maximum, the *He* I lines are systematically stronger in the giants. It should be noted, however, that we have no zero point for our scale of temperatures; a Bo giant may not have the same temperature as a Bo dwarf.

5. Morgan[10] has already pointed out that *Mg* II 4481 shows a null effect between about O9 and B5. My more complete material confirms this for the earlier classes, O9–B2. At B5 there seems to be a slight increase for the giants.

[8] *Astrophysical Journal*, **77**, 330, 1933.

[9] *Ibid.*, **74**, 248, 1931.

[10] *Ibid.*, **77**, 291, 1933.

6. *O* II behaves similarly. For the hottest stars there is no difference between giants and dwarfs, while for B0, B1, and B2 the strengthening is appreciable.

7. Silicon is especially interesting. *Si* II shows a null effect at about B2, but is markedly enhanced in the cooler giants. *Si* III has a null effect at O9, but is enhanced in the giants from B0 on. *Si* IV is enhanced in all giants observed by me. The result of these effects is that in several giants, notably in ϵ Canis Majoris, all three stages of ionization are visible simultaneously. I have found only one dwarf, γ Pegasi, where this is true, but even in this star *Si* IV is at the very limit of visibility. The result is interesting in connection with the theoretical work of Milne. It is somewhat disconcerting, however, that in the last paper on this subject Milne and Chandrasekhar[11] do not predict definite null effects on the hotter sides of the maxima.

8. The effect of absolute magnitude upon intensity for other elements may be estimated directly from the illustrations.

9. Ionized oxygen provides a remarkably interesting result. The lines of lower excitation potential come to a maximum at appreciably cooler temperatures than do lines of higher excitation potential. Consider, for example, the line 4303.8. Its lower excitation potential is 28.7 v. On the other hand, lines 4317 and 4320 have a potential of 22.9 v. All these belong to the quartet system. It is apparent from the illustration that λ 4304 comes to an earlier maximum than do λ 4317 and λ 4319. The same tendency may be noticed in other *O* II lines.

The *O* II lines near $H\gamma$, 4346, 4347, 4349, and 4351, are somewhat affected by the wings of $H\gamma$. Thus λ 4349 fades out much earlier than do 4415 and 4417, although their potentials are similar. This is probably caused by the greater opacity in cooler stars, resulting from the wing of $H\gamma$.

10. The peculiar difference, noted elsewhere,[12] between the intensities of the quartet lines of *O* II, 4346 and 4349 and those of the doublet lines 4347 and 4351, is clearly shown in the reproductions. The quartet lines are relatively stronger in most giants than in dwarfs.

[11] *Monthly Notices of the Royal Astronomical Society*, **92**, 150, 1932.

[12] Struve and Morgan, *Proceedings of the National Academy of Sciences*, **18**, 590, 1932.

(β Can. Maj. seems to be an exception; this star is, as I remarked before, not a typical giant.)

It is surprising, however, that this difference does not affect all quartets and doublets. Notice, for example, the two pairs of lines

$$4317\ y^4P-e^4P^0 \qquad 4415\ z^2P-e^2D^0\ ,$$
$$4320\ y^4P-e^4P^0 \qquad 4417\ z^2P-e^2D^0\ .$$

The first belongs to the quartets, the second to the doublets. Yet there is no appreciable difference in the relative intensities for giants and for dwarfs.

It seems to me more probable that this difference is of another origin. Notice the pair of faint *O* II lines at 4312 and 4313 which are clearly visible in the dwarf τ Scorpii. Then consider that these lines are practically invisible in all of the giants, in spite of the fact that the strong lines 4317 and 4320 are enormously strengthened in the giants. Does this not indicate that strong lines are much more strengthened in giants than are weak lines? If so, the phenomenon is probably similar to that which I observed in 17 Leporis,[13] where the multiplet intensities of the metallic lines are abnormal.

The idea is at least worth considering. I have measured many more faint *O* II lines in τ Scorpii than in any other star, in spite of the fact that typical giants like ζ Persei contain several stronger lines of *O* II than does τ Scorpii. Accurate measurements with the microphotometer would be valuable in this connection.

III

The great variety of interesting phenomena which come to light in a detailed study of stellar spectra makes it imperative that new and more refined methods than are at present available be used in stellar spectroscopy. That the B stars are not unique is shown by the work of Morgan on A stars. He found that the latter can be arranged satisfactorily into two parallel branches of stars which do not appreciably differ in absolute magnitude. He excluded the c stars, and was therefore dealing principally with stars of average luminosity. This result proves, I think conclusively, that two parameters are insufficient to describe the spectrum of an early type star. If this is

[13] *Op. cit.*, **76**, 85, 1932; J. A. Hynek, *ibid.*, **78**, 54, 1933.

the case, the present system of classification cannot be relied upon for accurate work, because the Harvard subdivisions are assigned as a compromise between several slightly conflicting criteria.

By making such a compromise we discard information which promises to throw light upon physical parameters not yet identified. To retain these data we must, for precise work, replace the Harvard subdivisions with numerical estimates of line intensities.

In the case of the B stars the principal criterion ought to be the intensity of *He* I 4472. This would put every star, without ambiguity, in its proper place. Thus, Maia would fall into the later classes, between γ Corvi and α Draconis. The intensities of other lines would then be somewhat conflicting—more conflicting, in fact, than they now are. Thus, the intensities of *Mg* II 4481 would not all be alike, even though *He* I 4471 would be of similar intensity. This would merely indicate that more than one physical parameter is effective. In order to separate the parameters we should have to observe more lines. By observing two lines, one of which is sensitive to changes of pressure while the other is not, we might eliminate pressure from other, unknown, factors.

This is essentially the procedure which I have used in my discussion of the B stars in section II, although I have not carried it through in arranging the table and the reproductions.

I wish to make it clear that I do not advise modifications or refinements of the Draper classification in spectroscopic work intended for statistical purposes. The Draper classification remains unsurpassed for investigations involving large numbers of stars.

YERKES OBSERVATORY
June 14, 1933

NOTE ADDED JULY 2

Dr. Morgan has called my attention to the fact that the stars 4 Lacertae, η Leonis, and 13 Monocerotis, which are included in my list of dwarfs, have been regarded as rather luminous stars by other investigators (Morgan, *Astrophysical Journal*, **77**, 294, 1933; E. Öpik and M. Olmsted, *Harvard College Observatory Circular*, No. 380, 1933). The explanation of this discrepancy is that in dividing the spectra into two groups I have tried to follow consistently the same criterion: thus, the hydrogen lines in 13 Monocerotis resemble those of γ Pegasi in the relative importance of the wings to the total absorptions of the lines; on the other

hand, α Cygni or β Orionis are almost entirely devoid of wings in the hydrogen lines, resembling such stars as ζ Persei or α Aurigae. The three stars mentioned above have relatively weak hydrogen lines and it is possible that the wings in them are relatively less pronounced than in other dwarfs, such as α Lyrae, but this will have to be investigated by means of accurate spectrophotometric measures. It is probable that my group of dwarfs includes among the later classes stars of somewhat different luminosity, although all of them are presumably less luminous than the stars which I have called giants. In order to avoid confusion, it would probably have been better not to use the definitions "giants" and "dwarfs" in my tables, but to regard the division as one based upon a purely observational criterion. This would also have been more consistent with the suggestions outlined in the last section. I might mention, however, that other methods of classifying early type stars into giants and dwarfs are no more satisfactory: thus the criterion of total intensity of hydrogen lines has given excellent results in statistical discussions. It is clear, however, that this method does not differentiate between real giants in which the hydrogen lines are free of Stark broadening, and therefore of small total intensity, and dwarfs in which the abundance of hydrogen is low. It would be of great interest to investigate this matter further, and to determine whether individual departures from the average abundance of hydrogen are actually measurable.

The peculiar differences in the intensity gradients of the *O* II absorption lines discussed on page 84 seem to be of great interest, especially in view of the observations by Morgan of lines of other elements (p. 158 of this issue). The phenomenon seems to be much more important than we had believed at first, and there is a wide field for accurate spectrophotometric investigations on line intensities. Dr. Elvey has undertaken such a study for certain early type stars. I am wondering whether the peculiar intensities of the *He* triplets and singlets, reported on page 82, are not in part different aspects of the same phenomenon. Since the triplets are systematically stronger than the corresponding singlet lines, part of the observational results could be interpreted as differences in the intensity gradients of the *He* lines. The observational results are still too incomplete to enable us to advance an explanation of this phenomenon. Attention might be called, however, to the fact that at least in two "abnormal" stars, 17 Leporis and ϵ Aurigae, the reversing layers are almost certainly enormously extensive, their thickness being roughly of the same order as the diameters of the stars. It is possible that the theoretical expressions of line contours derived for thin reversing layers are not applicable to such extensive stellar atmospheres.

CATALOGUE AND BIBLIOGRAPHY OF STARS OF CLASSES B AND A WHOSE SPECTRA HAVE BRIGHT HYDROGEN LINES[1]

By PAUL W. MERRILL and CORA G. BURWELL

ABSTRACT

The main *catalogue*, Table I, lists 410 stars of classes O, B, and A whose spectra have bright hydrogen lines, while Table II gives six anomalous objects whose spectra have bright lines of hydrogen and helium, but whose absorption spectra include titanium oxide bands. The exact meaning of the word "bright" as applied to lines having complex structure is discussed in the introduction. Notes to Table I record considerable unpublished data, besides calling attention to the chief features of a few of the more interesting peculiar spectra.

The *bibliography* includes 365 references to observational material concerning the objects in Tables I and II. The items referring to each star are indicated in a key list.

Discussion.—The numbers of stars discovered at various observatories are in Table IV. Tables V and VI show the distribution in type and magnitude. The largest numbers are in subdivision B3 and magnitude 8. Stars of the P Cygni type are listed in Table VII. Tables VIII, IX, X, and XI compare the numbers of Be stars in various intervals of type and magnitude with the total numbers of H.D. stars in the same intervals. Stars of class B2 have a stronger tendency toward emission than those of either earlier or later subdivisions. The proportion of bright-line stars decreases very rapidly from B3 to A0. The galactic distribution of Be stars is shown by Figs. *2a*, *2b*, and 3. The divergence from the galactic plane characteristic of the local system is less strongly marked than for non-emission B stars, probably because the emission stars are somewhat brighter intrinsically. Table XIII lists 12 areas rich in Be stars, among which star groups of two types may be recognized. An extremely interesting region is that of the double cluster in Perseus. The distribution of faint Cepheids is similar to that of faint Be stars.

INTRODUCTION

About 1910 a card catalogue of B-type stars whose spectra were known to have bright hydrogen lines was formed by one of us as a basis for further spectroscopic observations of these objects.[2] Harvard lists of peculiar spectra and W. W. Campbell's visual observations of the *Hα* line[3] were the chief sources. Cards have since been added as announcements of additional stars of this kind appeared, and it is believed that the list has been kept nearly complete. No general catalogue has appeared since the 1912 Harvard list of "Stars Having Bright Hydrogen Lines,"[4] which has 93 entries. The number

[1] *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington*, No. 471.

[2] *Lick Observatory Bulletins*, **7**, 162, 1913.

[3] *Astrophysical Journal*, **2**, 177, 1895.

[4] *Harvard Annals*, **56**, 182, 1912.

of Be stars now known exceeds 400, and descriptions of their spectra are widely scattered through astronomical publications. Several astronomers have therefore recently recommended the printing of the present catalogue. In its preparation we have had the advantage of referring to a somewhat similar unpublished catalogue compiled several years ago at the University of Michigan by the late Dr. R. H. Curtiss, who had offered its use for this purpose. It later became available through the kindness of Dr. W. C. Rufus and of Mr. W. J. Williams, who made a typewritten copy for our use. Other astronomers who have co-operated by supplying unpublished data concerning Be stars include V. M. Slipher, Lowell Observatory; W. E. Harper, J. A. Pearce, and C. S. Beals, Dominion Astrophysical Observatory; Dean B. McLaughlin, Observatory of the University of Michigan; Otto Struve, Yerkes Observatory; Frank C. Jordan, Allegheny Observatory; G. Shajn, Simeis Observatory; and several of our colleagues of the Mount Wilson Observatory. To all these gentlemen we express our cordial appreciation.

The main catalogue, Table I, includes all known stars of classes B and A whose spectra have bright hydrogen lines. It omits Wolf-Rayet stars and all other bright-line stars of class O, except five of classes O6–O9 whose bright lines resemble those characteristic of class Be. The stars omitted are those in the Harvard classes Oa, Ob, Oc, Od, Oe, and those additional stars with narrow emission lines at λλ 4634, 4640, and 4686, for which the Victoria observers have recently used the symbol "f."[5] The spectra of the omitted objects seem sufficiently different from those of typical Be stars, e.g., γ Cassiopeiae, to make it inadvisable to include them with Be stars in statistical studies.[6]

In Table II are six anomalous objects whose absorption spectra include titanium oxide bands together with lines having a partial resemblance to those of class K, but which are related to early type

[5] *Publications of the Dominion Astrophysical Observatory*, **5**, 110, 1930.

[6] Most spectra of classes Od and Oe (or O5–O9 with narrow emission at λλ 4634, 4640, and 4686) have dark hydrogen lines. A few may have one or more bright hydrogen lines of low intensity, but the structure of these lines probably differs from that regularly found in Be spectra. The star H.D. 108, included in Table I, offers an exception in that the bright hydrogen lines are well marked and not greatly different from those observed in certain Be stars.

spectra through the presence of bright lines of hydrogen and helium. These stars are not included in the statistical studies in the latter part of this contribution.

In dealing with lines having complex structure, such as those frequently present in Be spectra, the exact meaning to be attached to the word "bright" may require consideration. The condition that the intensity-curve of the line rise above that of the adjacent continuous spectrum is of course sufficient, but it is not necessary. In

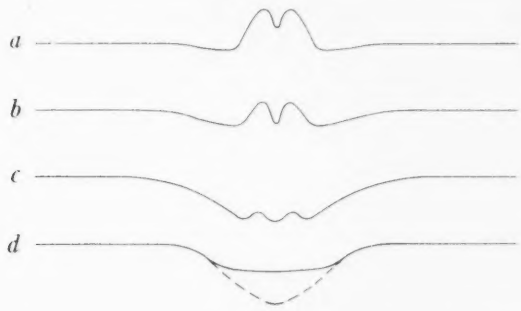


FIG. 1.—Illustrative intensity-curves of complex lines

the sequence of forms illustrated in Figure 1 it clearly seems appropriate to include *c* as well as *a* and *b* among the bright lines. Not to do so would terminate the sequence in an arbitrary and physically unjustifiable manner. When, however, no maxima are seen, and the central portion of the curve merely lies above the hypothetical extension of the wings, as in *d*, we consider it inadvisable to call the line bright.[7] A practical criterion seems to be that definite maxima (not caused by the superposition of lines of other elements) shall be seen.[8] The physical significance of this criterion is established by the fact that if a certain member of the Balmer series has a curve similar

[7] If it is thought that the appearance arises from incipient emission, two tests may be applied: (1) the line may be observed in such a way as to accentuate indistinct maxima (by using greater purity or higher dispersion or a more contrasty emulsion) or (2) the Balmer lines of longer wave-length may be photographed; this is the most decisive test, applicable to all lines except $H\alpha$.

[8] The same criterion might be useful for the bright components of the H and K lines in late-type spectra (Adams and Joy, *Publications of the Astronomical Society of the Pacific*, **43**, 407, 1931).

to *c*, the members at longer wave-length have curves like *b* or *a*. In the spectra of many stars listed in Table I the structure of $H\gamma$ is qualitatively like *c*, and in a smaller number $H\beta$ is similar. We think, however, that in every instance the emission at the $H\alpha$ line rises above the level of the continuous spectrum. If a spectrum should be found in which $H\alpha$ is similar to *c* but with all the other hydrogen lines wholly dark, we should still be inclined to include it in the Be group.

DESCRIPTION OF TABLES I AND II

Col.	Heading	
1	MWC	Mount Wilson Catalogue current number.
2	H.D.	The number of the star in the *Henry Draper Catalogue* (*Harvard Annals*, **91–99**). Numbers larger than 225,300 are from the *Henry Draper Extension* (*ibid.*, **100**).
3	Desig.	The name by which the star is commonly known or the *Durchmusterung* number (given in the same system as that employed in the *Henry Draper Catalogue*). For a few faint stars lacking *Durchmusterung* numbers, MW refers to the *Mount Wilson discovery lists of Be stars* (*Mt. Wilson Contr.*, Nos. 294 and 456; *Astrophysical Journal*, **61**, 389, 1925, and **76**, 156, 1932).
4, 5	R.A. / Dec.	Right ascension and declination for 1900.
6, 7	*l*, *b*	Galactic longitude and latitude. The usual position for the north galactic pole, R.A. = 12^h40^m, Dec. = $+28°$ (1900), has been assumed.
8	Mag.	Most of the values are *visual* magnitudes determined by the Harvard observers. The B.D., the C.D., or the C.P.D. magnitudes are given for most stars not in the H.D., but for stars in the double cluster in Perseus the magnitudes by Trumpler (*Publications of the Astronomical Society of the Pacific*, **38**, 350, 1926) or by van Maanen (*Mt. Wilson Contr.*, No. 205) have been substituted. For a few faint stars the values (in italics) are photographic magnitudes determined by Mr. M. L. Humason at Mount Wilson.
9	Type	The symbols have their usual meaning. In general the classifications made from slit spectrograms at Mount Wilson (*Contr.* Nos. 262, 294, 456) or at Victoria (*Publications of the Dominion Astrophysical Observatory*, **5**, No. 2) have been used. Most of these agree closely with the Harvard determinations, especially for the brighter stars. In many in-

stances Mount Wilson spectrograms have been re-examined to check the classification and especially to determine whether the symbols "n" or "s" should be included. The spectra of many, possibly all, of the stars in Tables I and II are variable to a greater or less extent. In certain stars the variation appears to affect only the bright lines; in others, the variations are more extensive, and in a few instances are so general that the classification would depend on the date of observation. It has not seemed feasible to indicate these changes in the catalogue. A few special instances are remarked upon in the notes to Table I, but for detailed information the original papers should be consulted.

TABLE I

STARS OF CLASSES B AND A WHOSE SPECTRA HAVE BRIGHT HYDROGEN LINES

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
1	108	*2363*	$0^h\ 0^m.9$	+63° 7′	86°	+ 1°	7.4	O6ep
2	144	2107	0 1.2	+63 37	86	+ 2	5.5	B9nea
3	.....	*2829*	0 1.6	+60 4	85	− 2	9.5	Bone
4	698	28	0 6.3	+57 39	85	− 4	7.1	B8sea
5	.....	39	0 14.8	+61 54	87	0	8.9	B(0)e
6	2789	35	0 26.3	+66 36	89	+ 5	8.2	B2ne
7	2905	κ Cas	0 27.3	+62 23	89	0	4.2	B0sea
8	4180	ο Cas	0 39.2	+47 44	90	−14	4.7	B4neβ
9	5394	γ Cas	0 50.7	+60 11	91	− 2	2.2	Bone
10	6343	^{g}129	0 59.4	+65 26	92	+ 3	7.1	B5eβ
11	.....	180	1 5.9	+60 47	93	− 1	9.4	B(3)e
12	7636	*240*	1 11.2	+57 6	94	− 5	7.6	B2ne
13	9105	259	1 24.6	+62 51	95	+ 1	7.5	B5s(e)
14	.....	*271*	1 27.9	+63 7	95	+ 2	8.2	B(8)eβ
15	.....	285	1 32.2	+62 57	96	+ 2	8.6	B(8)e
16	10516	φ Per	1 37.4	+50 11	99	−11	4.2	Bone
17	.....	MW 101	1 40.8	+60 12	97	− 1	*12.2*	Pec.
18	.....	358	1 42.7	+60 33	98	− 1	9.0	B(3)ne
19	232552	398	1 45.9	+54 50	99	− 6	7.6	B(2)ne
20	11554	425	1 48.4	+57 24	99	− 3	9.2	B(3)e
21	11606	331	1 48.8	+58 47	99	− 2	7.0	B3ne
22	.....	261	1 50.1	+63 33	98	+ 3	9.1	Bne
23	12302	*356*	1 55.6	+59 12	100	− 1	8.2	B3e
24	236935	*469*	1 57.2	+58 0	100	− 2	9.1	B4ne
25	12856	429	2 0.9	+56 38	101	− 3	8.4	B(2)ne
26	12882	295	2 1.1	+64 33	99	+ 4	7.5	B(2)ne
27	13051	432	2 2.6	+56 31	101	− 4	8.0	B(0)ne
28	.....	515	2 5.7	+57 13	101	− 3	9.3	B(3)e
29	13661	*486*	2 8.1	+54 4	103	− 6	8.6	B(3)ne
30	.....	MW 112	2 9.0	+56 32	102	− 3	*11.4*	Be
31	13854	471	2 9.9	+56 36	102	− 3	6.4	B1sea
32	14134	522	2 12.1	+56 40	102	− 3	6.7	B3sea
33	.....	534	2 12.4	+56 37	102	− 3	*10.1*	Bne
34	.....	559	2 14.2	+56 51	103	− 3	*10.7*	Be
35	.....	Comp ο Cet	2 14.3	− 3 26	137	−57	10v	Bep
36	.....	563	2 14.7	+56 40	103	− 3	*9.6*	B3e
37	14422	565	2 14.7	+56 56	103	− 3	9.4	Bne
38	.....	566	2 14.8	+56 42	103	− 3	*10.1*	B3e
39	.....	Anon	2 15.0	+56 43	103	− 3	*10.6*	B4e
40	.....	573	2 15.0	+56 38	103	− 3	*9.9*	B3e
41	.....	582	2 15.3	+56 50	103	− 3	*10.2*	B(3)e
42	.....	458	2 16.2	+58 31	102	− 1	9.4	B(3)ne
43	.....	MW 117	2 16.2	+57 4	103	− 3	*10.6*	Be
44	14605	*605*	2 16.5	+56 8	103	− 3	9.7	B(2)ne
45	14818	*612*	2 18.2	+56 10	103	− 3	6.2	B1sea
46	.....	624	2 19.6	+56 39	103	− 3	9.3	B(2)ea
47	15238	488	2 22.2	+60 13	102	+ 1	8.4	B8ea
48	15450	642	2 24.2	+56 27	104	− 3	8.7	Bone
49	15472	182	2 24.4	+70 30	99	+10	8.0	B4ne
50	.....	MW 122	2 24.6	+60 56	103	+ 1	*11.0*	Be

TABLE I—*Continued*

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
51	.....	510	2^h26^m3	+60 33	103	+ 1	9.0	B(9)eα
52	.....	MW 124	2 27.5	+59 0	103	0	*11.2*	Be
53	.....	*516*	2 28.4	+60 10	103	+ 1	9.5	Be
54	.....	492	2 29.3	+58 56	104	0	9.5	Be
55	.....	607	2 32.8	+57 21	105	− 1	9.5	Be
56	.....	MW 128	2 35.0	+60 50	104	+ 2	*11.6*	Bep
57	.....	487	2 42.3	+61 41	104	+ 3	9.4	B(0)ne
58	.....	727	2 44.1	+56 32	107	− 1	9.5	B(5)e
59	.....	606	2 51.5	+60 12	106	+ 2	9.1	Be
60	237060	*554*	2 56.7	+59 2	107	+ 2	8.8	B(5)neα
61	19243	*525*	3 0.7	+62 0	106	+ 4	6.5	B2e
62	237091	612	3 7.3	+59 32	108	+ 3	8.8	Be
63	20017	870	3 7.9	+48 19	114	− 7	7.9	Bne
64	20134	625	3 9.1	+59 41	108	+ 3	7.5	B2e
65	20336	H.R. 985	3 11.2	+65 17	105	+ 8	4.8	B3e
66	237134	647	3 17.0	+59 54	109	+ 4	8.8	Bne
67	21212	*587*	3 20.3	+62 9	108	+ 6	8.7	B2e
68	21650	696	3 24.6	+41 25	120	−11	7.2	B5ne
69	22192	ψ Per	3 29.4	+47 51	117	− 5	4.3	B5ne
70	22298	698	3 30.3	+54 50	113	+ 1	8.4	B2ne
71	.....	623	3 31.9	+61 31	109	+ 6	8.7	B2ne
72	23302	Electra	3 39.0	+23 48	134	−23	3.8	B5neα
73	23480	Merope	3 40.4	+23 39	134	−22	4.2	B5ne
74	23630	Alcyone	3 41.5	+23 48	135	−22	3.0	B5ne
75	23862	Pleione	3 43.3	+23 51	135	−22	5.2	B8n(e)
76	23982	458	3 44.3	+63 11	109	+ 8	8.1	B3e
77	24479	628	3 48.6	+62 47	110	+ 8	4.9	B0neα
78	24534	X Per	3 49.1	+30 45	131	−16	6 v	B0ne
79	24560	816	3 49.3	+44 38	122	− 5	7.8	B(2)ne
80	25348	*752*	3 56.6	+53 3	117	+ 2	8.2	B(1)ne
81	25940	c Per	4 1.4	+47 27	121	− 2	4.0	B3ne
82	26420	830	4 5.7	+41 52	126	− 6	7.6	B3neα
83	26906	904	4 10.1	+45 58	124	− 2	8.6	B(3)ne
84	.....	MW 143	4 11.6	+55 46	117	+ 5	*11.5*	Bep
85	232971	778	4 23.7	+53 36	120	+ 5	9.0	B(5)ne
86	28497	893	4 24.5	−13 17	176	−36	5.5	B3ne
87	237209	831	4 33.0	+57 43	117	+ 9	8.8	B(3)e
88	29866	1032	4 37.3	+40 36	131	− 2	6.1	B4ne
89	30076	56 Eri	4 39.3	− 8 41	173	−31	5.9	B5ne
90	.....	MW 146	4 40.0	+46 3	127	+ 2	*10.0*	Be
91	.....	974	4 43.2	+41 30	131	− 1	9.2	B0ne
92	30614	9 (α) Cam	4 44.1	+66 10	111	+15	4.4	O9.5eα
93	31293	AB Aur	4 49.4	+30 24	140	− 7	7.5v	Aoep
94	.....	1031	4 54.2	+41 7	132	+ 1	9.0	B(3)ne
95	32256	(N.G.C. 1763)	4 56.6	−66 34	244	−36	.....	Pec.
96	32343	11 Cam	4 57.4	+58 50	118	+12	5.3	B3e
97	32763	343	5 0.3	−70 20	248	−35	*9.6*	Pec.
98	32991	105 Tau	5 2.0	+21 34	149	−10	6.0	B3ne
99	33152	1021	5 3.2	+36 53	137	0	7.8	B2e
100	33232	1196	5 3.7	+40 53	134	+ 2	8.1	B(3)e
101	33461	1106	5 5.3	+41 6	134	+ 2	8.0	B(1)e
102	33540	.....	5 5.8	−71 3	249	−34	*12.3*	Beq
103	33604	1213	5 6.3	+40 5	135	+ 2	7.3	B3se

TABLE I—*Continued*

MWC*	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
104	33988	12 Aur	5 9.0	+46 19	130	+ 6	6.9	B5ne
105	34664	In N.G.C. 1871	5 14.0	−67 34	245	−34	*11.4*	Beq
106	.....	Anon	5 14.4	−69 28	247	−34	*11.4*	Beq
107	34921	1160	5 15.8	+37 35	138	+ 2	7.4	Bone
108	35343	S Dor	5 18.9	−69 21	246	−33	9 v	Beq
109	35345	1095	5 19.0	+35 33	140	+ 1	8.4	B2e
110	35439	25 Ori	5 19.6	+ 1 45	169	−17	4.7	B3ne
111	36576	120 Tau	5 27.6	+18 29	155	− 6	5.5	B3ne
112	.....	Anon	5 28.5	−69 4	246	−32	*13.0*	Beq
113	.....	(383)	5 29.0	−69 13	246	−32	*12.2*	Beq
114	37115	1330	5 31.0	− 5 41	177	−18	8.2	B5ne
115	37202	ζ Tau	5 31.7	+21 5	153	− 4	3.0	B3e
116	37330	1138	5 32.7	+ 0 55	171	−14	7.2	B8ne
117	37490	ω Ori	5 33.9	+ 4 4	168	−13	4.5	B3e
118	37657	*1376*	5 35.1	+43 0	135	+ 8	7.0	B3ne
119	37795	α Col	5 36.0	−34 8	206	−28	2.8	B8ne
120	37806	1344	5 36.1	− 2 46	175	−15	8.6	Aoe
121	37836	401	5 36.2	−69 44	247	−32	*10.5*	Beq
122	37967	1015	5 37.2	+23 10	152	− 2	6.1	B3ne
123	37974	420	5 37.2	−69 26	246	−32	*11.3*	Beq
124	38010	941	5 37.5	+25 24	150	− 1	6.9	B3ne
125	38191	958	5 38.9	+21 25	154	− 3	9.5	Bne
126	38489	478	5 41.0	−69 26	246	−31	*12.0*	Beq
127	39340	985	5 46.9	+26 25	151	+ 2	8.1	B3ne
128	248753	1019	5 47.3	+25 43	151	+ 1	*8.4*	Bone
129	39478	992	5 47.8	+26 24	151	+ 2	8.4	B2ne
130	39557	1203	5 48.3	+ 0 46	173	−11	8.9	B(8)ne
131	40978	1091	5 57.2	+46 33	134	+13	7.0	B3ne
132	41117	χ^2 Ori	5 58.0	+20 8	157	+ 1	4.7	B1sea
133	41335	1391	5 59.4	− 6 42	181	−12	5.1	B2(n)e
134	42054	2655	6 3.5	−34 18	208	−22	5.9	B5ne
135	253214	1309	6 6.4	+20 7	158	+ 2	*9.4*	Bone
136	43285	1172	6 10.3	+ 6 6	171	− 4	6.0	B5ne
137	.....	MW 229	6 13.0	+15 19	163	+ 1	*11.2*	Pec.
138	44458	1460	6 16.8	−11 44	188	−11	5.5	B2ne
139	44637	1176	6 17.7	+15 9	164	+ 2	7.7	B3e
140	45314	1296	6 21.6	+14 57	165	+ 3	7.1	B2ne
141	45542	ν Gem	6 23.0	+20 17	160	+ 6	4.1	B5ne
142	45677	*1500*	6 23.7	−13 0	190	−10	7.5	Bep
143	45725	β Mon Pr	6 24.0	− 6 58	184	− 7	4.7	B3ne
144	45727	β Mon Fl	6 24.0	− 6 58	184	− 7	5.6	B3ne
145	45910	1267	6 25.2	+ 5 57	173	0	6.7	Beq
146	45995	1204	6 25.6	+11 19	168	+ 2	5.8	B2ne
147	259431	1172	6 27.6	+10 24	169	+ 2	*9.0*	B2e
148	259440	1291	6 27.6	+ 5 52	173	0	*9.6*	B(5)ne

* *Harvard Bulletin*, No. 891, received after the completion of Table I, lists two additional stars of the P Cygni type in the Large Magellanic Cloud.

Desig.	R.A. (1900)	Dec. (1900)	Mag.
C.P.D.−69°427	$5^h14^m39^s$ 5 37 32	−69°38′.2 −69 38.1	11.6 11.1

TABLE I—*Continued*

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
149	259597	1388	6^h28^m1	+ 8° 24′	171°	+ 1°	*8.8*	B(o)ne
150	47054	1710	6 31.6	− 5 8	184	− 4	5.5	B8neα
151	.....	R Mon	6 33.7	+ 8 49	171	+ 3	13 v	Pec.
152	48917	10 CMa	6 40.7	−30 58	208	−14	5.2	B3ne
153	49787	1815	6 45.0	− 5 24	185	− 1	7.3	B3e
154	49977	*1682*	6 45.9	−14 0	193	− 5	7.9	B2ne
155	50013	κ CMa	6 46.1	−32 23	210	−13	3.8	B2ne
156	50083	1448	6 46.5	+ 5 13	176	+ 4	6.8	B2e
157	50123	3717	6 46.6	−31 36	209	−13	5.6	B8ne
158	50138	1775	6 46.7	− 6 51	187	− 2	6.6	B8e
159	50209	1468	6 47.1	− 0 10	181	+ 1	8.3	B(5)ne
160	51354	1423	6 51.9	+18 2	165	+11	7.1	B(3)ne
161	51480	1774	6 52.4	−10 41	191	− 2	7.0	B8eq
162	51585	.....	6 52.8	+16 28	167	+10	.....	Beq?
163	52244	1694	6 55.3	−16 3	196	− 4	9.0	B5e
164	52721	1747	6 57.2	−11 9	192	− 1	6.6	B3e
165	53179	Z CMa	6 59.0	−11 24	192	− 1	9.1	Beq
166	53367	1848	6 59.7	−10 18	191	− 1	7.0	B1ne
167	54309	4908	7 3.2	−23 41	204	− 6	5.8	B3ne
168	55135	1908	7 6.6	−10 16	192	+ 1	7.2	B4ne
169	55271	1791	7 7.1	−21 38	202	− 4	6.7	B5ne
170	56014	27 CMa	7 10.2	−26 10	207	− 6	4.7	B5e
171	56139	ω CMa	7 10.7	−26 35	207	− 6	3.8	B3e
172	56806	1769	7 13.4	−18 39	200	− 2	9.3	Be
173	57150	ν^1 Pup	7 14.8	−36 33	216	−10	4.7	B3ne
174	57386	1856	7 15.9	− 8 15	192	+ 4	8.1	B5ne
175	58011	4439	7 18.6	−25 49	207	− 4	7.0	B1e
176	58050	1564	7 18.8	+15 43	170	+16	6.4	B3e
177	58343	*1810*	7 20.1	−16 0	199	+ 1	5.2	B3se
178	58715	β CMi	7 21.7	+ 8 29	177	+13	3.1	B8ne
179	58978	1874	7 22.8	−22 53	205	− 2	5.5	B2ne
180	.....	2040	7 24.5	−13 34	197	+ 3	9.0	B2ne
181	59497	1962	7 25.1	−21 38	204	− 1	8.4	B3ne
182	59773	1979	7 26.4	−21 35	204	0	8.1	B3e
183	60606	z Pup	7 30.2	−36 7	217	− 7	5.5	B5e
184	60848	1623	7 31.4	+17 7	170	+19	7.7	O7ne
185	62753	3379	7 40.4	−40 5	222	− 7	6.7	B2ne
186	63462	o Pup	7 43.9	−25 42	210	+ 1	4.6	B3e
187	64109	1843	7 47.2	+ 4 5	184	+17	8.3	B8ne
188	65079	1848	7 51.9	+ 3 14	186	+17	7.7	B3ne
189	65176	1900	7 52.4	− 1 20	190	+15	8.1	B(5)ne
190	65875	2379	7 55.8	− 2 36	192	+15	6.4	B2e
191	66700	5452	7 59.6	−31 24	217	+ 1	8.0	B3e
192	68980	r Pup	8 9.7	−35 35	221	0	4.8	B3ne
193	69404	3951	8 11.7	−46 10	230	− 6	6.6	B3e
194	72754	3621	8 29.4	−49 16	234	− 5	7.3	Be
195	75311	f Car	8 44.1	−56 25	241	− 8	4.6	B3ne
196	78764	E Car	9 4.8	−70 8	253	−15	4.9	B3ne
197	83953	I Hya	9 36.7	−23 8	224	+22	4.7	B3ne
198	87643	1865	10 1.1	−58 11	250	− 2	9.1	Be
199	88661	2781	10 8.3	−57 34	251	− 1	6.1	B2e
200	89249	*3389*	10 12.6	−55 5	250	+ 1	9.1	Be
201	89890	J Vel	10 17.2	−55 33	251	+ 1	4.6	B5e

TABLE I—*Continued*

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
202	90177	*2145*	$10^h19^m.4$	−59° 8′	253°	− 2°	7.9	Be
203	.....	3261	10 23.8	−57 9	252	0	*9.2*	Be
204	90966	1595	10 24.9	−62 40	255	− 5	6.7	B3e
205	91120	*3181*	10 26.1	−13 5	227	+38	5.5	B9nea
206	.....	Anon	10 26.7	−71 34	260	−12	.....	Pec.
207	.....	2193	10 28.0	−59 46	254	− 2	*8.9*	Be
208	91465	p Car	10 28.5	−61 11	255	− 3	3.6	B5ne
209	92714	*3671*	10 37.2	−58 3	254	0	*9.4*	Be
210	.....	2160	10 37.6	−60 15	255	− 2	*9.2*	Be
211	92964	2581	10 38.9	−58 42	255	0	5.4	B1se
212	93128,9	*2617,8*	10 40.1	−59 2	255	0	7.1	Be
213	93190	2637	10 40.5	−58 46	255	0	8.9	Be
214	93308	η Car	10 41.2	−59 10	255	− 1	7 v	Pec.
215	94878	2855	10 52.0	−59 52	257	− 1	8.5	Beq
216	94910	2860	10 52.2	−59 55	257	− 1	7.6	Beq
217	97151	3100	11 5.8	−59 33	258	0	8.0	B2e
218	102776	j Cen	11 44.8	−63 14	264	− 2	4.5	B5ne
219	105435	δ Cen	12 3.2	−50 10	264	+11	2.9	B3ne
220	105675	2166	12 4.8	−63 26	266	− 2	9.4	Be
221	107348	ζ Crv	12 15.4	−21 39	263	+40	5.3	B8ne
222	109387	κ Dra	12 29.2	+70 20	92	+48	3.9	B5e
223	110335	4393	12 36.2	−59 8	270	+ 3	5.0	B8e
224	110432	2898	12 36.9	−62 30	270	0	6.0	B1ne
225	112091	μ^2 Cru	12 48.8	−56 37	271	+ 5	5.5	B3ne
226	113120	1553	12 56.3	−70 56	271	− 9	6.0	B3ne
227	114200	1567	13 3.9	−70 16	272	− 8	9.6	Be
228	116781	3270	13 20.7	−62 8	275	− 1	8.8	Be
229	120324	μ Cen	13 43.6	−41 59	282	+18	3.3	B3e
230	120991	8931	13 47.7	−46 39	282	+14	5.9	B3e
231	124367	6206	14 8.0	−56 37	282	+ 3	5.2	B3ne
232	127972,3	η Cen	14 29.2	−41 43	291	+16	2.6	B3ne
233	128293	2622	14 30.9	−67 47	280	− 8	6.9	B3e
234	135160	5698	15 8.5	−60 32	287	− 4	6.0	B1e
235	137387	κ^1 Aps	15 20.6	−73 2	281	−15	5.6	B5ne
236	138403	1889	15 26.7	−71 34	283	−14	*9.0*	Beq
237	138749	θ CrB	15 28.9	+31 42	16	+53	4.2	B5ne
238	141969	3171	15 46.7	−65 52	288	−10	*9.2*	Beq
239	142983	4302	15 52.6	−13 59	324	+27	4.7	Apea
240	143448	6348	15 55.2	−60 13	292	− 7	*7.8*	B3e
241	148184	χ Oph	16 21.2	−18 14	326	+19	4.8	B3e
242	151895	.....	16 45.1	−64 4	293	−14	*12.5*	Beq
243	152236	ζ^1 Sco	16 47.0	−42 12	311	0	4.9	B1seq
244	153222	11105	16 52.9	−49 6	306	− 5	9.5	Boe
245	153261	6964	16 53.2	−58 48	298	−11	6.3	Boe
246	153879	10676	16 56.9	−51 15	305	− 7	8.6	B3e
247	.....	MW 168	16 58.1	−33 50	319	+ 3	*12.5*	Bep
248	154154	11424	16 58.6	−48 17	307	− 6	8.6	Boe
249	154218	11217	16 59.0	−36 36	317	+ 1	7.7	B5ne
250	154243	11221	16 59.2	−36 27	317	+ 1	8.3	B2e
251	154450	11320	17 0.4	−35 37	317	+ 2	8.5	Boe
252	155806	11875	17 8.7	−33 26	320	+ 2	5.5	O8e
253	155851	12518	17 9.0	−32 34	321	+ 2	8.0	Bone
254	156325	12573	17 11.8	−32 27	321	+ 2	6.4	B6nea

TABLE I—*Continued*

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
255	156468	11463	17^h12^m6	$-37°54'$	317°	− 2°	8.0	B2e
256	.....	11482	17 13.8	−35 39	319	− 1	9.6	Be
257	156702	11773	17 14.0	−38 33	316	− 2	8.4	B5e
258	157042	ι Ara	17 15.8	−47 23	310	− 7	5.5	B3ne
259	157832	11530	17 20.5	−46 57	310	− 8	7.3	B2e
260	158319	4526	17 23.5	−16 31	336	+ 8	8.7	B5ne
261	158427	α Ara	17 24.1	−49 48	308	−10	3.0	B3ne
262	159684	11750	17 30.9	−35 17	321	− 3	7.6	B2e
263	160095	12319	17 32.9	−33 29	323	− 3	8.7	B8e
264	160202	13086	17 33.5	−32 9	324	− 2	6.9	B(1)ne
265	.....	RT Ser	17 34.3	−11 53	342	+ 8	12 v	Pec.
266	160529	12361	17 35.3	−33 27	323	− 3	6.7	A4sea
267	161044	11816	17 38.2	−46 3	313	−10	11.0	Beq
268	161103	11872	17 38.5	−27 12	329	0	7.9	Bone
269	161114	XX Oph	17 38.6	− 6 14	347	+10	10 v	Pec.
270	.....	MW 174	17 39.5	−30 10	327	− 2	*11.5*	Bep
271	161306	4598	17 39.7	− 9 46	344	+ 8	8.3	B(0)ne
272	.....	11944	17 41.9	−27 59	329	− 1	9.0	Beq
273	162718	13585	17 47.3	−24 45	332	− 1	9.0	Bone
274	163181	13517	17 49.7	−32 27	326	− 5	6.6	B1se
275	163296	4779	17 50.3	−21 56	335	0	6.6	A2e
276	163454	*14987*	17 51.1	−31 0	327	− 5	7.9	B1ne
277	163868	12700	17 53.3	−33 24	325	− 6	7.2	B2ne
278	164284	66 Oph	17 55.3	+ 4 22	359	+12	4.8	B5ne
279	164447	3494	17 56.1	+19 31	13	+18	6.4	B0e
280	164906	13832	17 58.3	−24 24	334	− 3	9.0	B(0)ne
281	165285	4836	18 0.1	−19 58	338	− 1	8.7	B2ne
282	166188	4815	18 4.4	−18 13	340	− 1	9.4	B2e
283	166256	3540	18 4.7	+13 28	8	+14	8.4	Aone
284	166566	4856	18 6.1	−15 42	342	0	8.1	B1se
285	166666	4861	18 6.6	−15 36	342	0	9.4	B2e
286	166734	4625	18 6.9	−10 46	347	+ 2	8.3	Boea
287	.....	5060	18 9.7	−20 23	339	− 3	9.0	B(0)ne
288	167362	15469	18 9.7	−30 54	329	− 8	11.8	Pec.
289	168135	4991	18 13.2	−12 29	346	0	8.1	B8nea
290	168229	4909	18 13.6	−18 16	341	− 3	9.7	B(1)ne
291	168607	4829	18 15.5	−16 25	343	− 2	8.9	Aose
292	168957	*3395*	18 17.3	+25 1	20	+16	6.9	B5e
293	169226	5034	18 18.6	−12 15	347	− 1	9.1	Be(q)
294	169454	5039	18 19.6	−14 2	345	− 2	6.8	Bose
295	169515	RY Sct	18 19.9	−12 45	346	− 2	9 v	Pec.
296	169805	5007	18 21.3	−19 1	341	− 5	8.7	B1ne
297	.....	MW 181	18 22.4	− 3 55	354	+ 2	*11.0*	Be
298	170061	5062	18 22.4	−14 47	345	− 3	10.6	Bone
299	170235	13170	18 23.2	−25 19	336	− 8	6.2	B2e
300	.....	MW 182	18 24.0	− 6 9	353	+ 1	*10.0*	Bep
301	171012	4994	18 27.3	−18 26	342	− 6	7.0	Bosea
302	171348	4790	18 29.3	−22 10	339	− 8	8.1	B3e
303	172094	5063	18 36.5	−15 57	345	− 7	8.3	Bpe
304	173219	4689	18 39.1	− 7 13	354	− 3	8.3	B1e
305	174105	3573	18 43.8	+15 17	14	+ 6	6.9	B8ne
306	174638,9	β Lyr	18 46.4	+33 15	31	+14	4 v	Bep
307	174886	4848	18 47.7	−10 21	352	− 6	8.1	B3e

TABLE I—*Continued*

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
308	175863	1929	18^h52^m3	+59° 53′	57°	+22°	6.9	B4e
309	177015	5381	18 57.7	−20 16	344	−13	7.6	B3e
310	177648	3549	19 0.5	+23 11	23	+ 6	6.9	B3e
311	178175	5312	19 2.4	−19 27	345	−14	5.4	B3e
312	180398	3861	19 11.3	+12 56	15	− 1	7.7	B(3)ne
313	181615,6	υ Sgr	19 16.0	−16 8	350	−15	4.6	Ave
314	.....	3887	19 17.0	+14 42	17	− 1	9.5	Pec.
315	.....	MW 187	19 19.9	+29 28	31	+ 6	*10.0*	Bep
316	.....	3687	19 20.5	+22 35	25	+ 2	8.6	B2e
317	183143	4085	19 23.0	+18 5	21	− 1	6.9	B0seα
318	183362	3465	19 24.1	+37 44	38	+ 9	6.4	B3ne
319	184279	4065	19 28.6	+ 3 34	9	− 9	6.8	B2se
320	.....	4285	19 41.3	+ 5 44	12	−11	8.5	B5ne
321	187399	3754	19 44.7	+29 10	33	+ 1	7.7	B0eβ
322	187567	4252	19 45.5	+ 7 39	15	−11	6.4	B3ne
323	187811	12 Vul	19 46.8	+22 21	27	− 3	4.9	B5ne
324	.....	3723	19 51.1	+26 19	31	− 2	8.7	B(5)ne
325	190073	4393	19 58.1	+ 5 28	14	−14	7.9	A0ep
326	190603	3925	20 0.7	+31 56	37	− 1	5.7	B0seα
327	227611	3950	20 2.0	+35 37	40	+ 1	*9.5*	Be
328	190944	2846	20 2.3	+46 24	49	+ 7	8.8	B(2)e
329	191610	b^2Cyg	20 5.7	+36 33	41	+ 1	4.8	B3ne
330	228041	3998	20 6.2	+35 12	41	0	*9.6*	B(3)ne
331	192044	20 Vul	20 7.8	+26 11	33	− 5	5.9	B8ne
332	192445	*4026*	20 9.8	+36 2	42	0	7.1	B2ne
333	228438	3946	20 10.1	+36 20	42	0	*9.0*	Bone
334	228548	4098	20 11.4	+39 40	45	+ 2	*10.8*	B(2)ne
335	192054	4120	20 12.6	+15 33	25	−12	7.3	A2e
336	193009	*4018*	20 12.9	+32 4	39	− 3	7.0	Bone
337	.....	MW 195	20 13.8	+36 34	43	0	*10.0*	B(2)e
338	193237	P Cyg	20 14.1	+37 43	43	0	4.9	B1eq
339	193516	3881	20 15.5	+37 28	43	0	8.8	B1(e)
340	.....	*4124*	20 17.0	+41 2	47	+ 2	9.5	B(2)e
341	193911	25 Vul	20 17.7	+24 7	33	− 8	5.4	B8ne
342	.....	MW 197	20 19.5	+39 10	45	0	*10.8*	Be
343	194335	3916	20 20.0	+37 10	44	− 1	5.7	B3ne
344	229221	4062	20 20.1	+38 11	45	0	*10.0*	B(0)e
345	194883	2348	20 23.0	+54 22	58	+ 9	7.2	B3e
346	195407	4095	20 26.0	+36 39	44	− 2	7.7	B3e
347	195592	3630	20 27.2	+43 59	50	+ 2	7.2	B1se
348	195907	4126	20 29.0	+31 19	40	− 6	7.6	B2e
349	.....	MW 203	20 29.2	+40 19	47	0	*13.2*	Bep
350	196712	5328	20 34.0	− 2 46	12	−26	6.3	B9e
351	197345	α Cyg	20 38.0	+44 55	52	+ 1	1.3	A2seα
352	198183	λ Cyg	20 43.5	+36 7	46	− 5	4.5	B6e
353	198478	3291	20 45.5	+45 45	53	+ 1	4.9	B2seα
354	198512	2495	20 45.7	+53 32	59	+ 6	8.0	B2ne
355	198895	*2429*	20 48.4	+55 7	61	+ 7	8.3	B2e
356	199218	4354	20 50.7	+40 20	50	− 3	6.5	B5ne
357	199356	4368	20 51.6	+39 55	50	− 4	7.0	B3ne
358	199478	*3111*	20 52.4	+47 2	55	+ 1	5.8	B8seα
359	200120	f^1 Cyg	20 56.4	+47 8	56	0	4.9	B3ne
360	200310	60 Cyg	20 57.6	+45 46	55	− 1	5.2	B3ne

TABLE I—*Continued*

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
361	200775	1283	$21^h\ 0^m.4$	+67° 47′	71°	+14°	7.2	B5e
362	201522	3198	21 5.1	+46 51	57	− 1	7.8	B3ne
363	201733	*3718*	21 6.4	+45 6	56	− 2	6.5	B5e
364	202904	υ Cyg	21 13.8	+34 29	49	−11	4.4	B3ne
365	203025	*2309*	21 14.6	+58 10	66	+ 6	6.4	B3e
366	203374	2112	21 16.7	+61 25	68	+ 8	6.6	Bone
367	203467	6 Cep	21 17.3	+64 27	70	+10	5.2	B3ne
368	203699	4692	21 18.8	+13 37	34	−26	6.7	B5e
369	203731	4503	21 19.0	+40 16	54	− 7	7.4	B3ne
370	204722	3941	21 25.5	+43 54	57	− 5	7.5	B3ne
371	205060	4123	21 27.7	+42 16	56	− 7	7.1	B5(n)e
372	239703	*2289*	21 31.5	+59 1	68	+ 5	9.0	B(3)ne
373	205637	ϵ Cap	21 31.5	−19 54	0	−46	4.7	B5pe
374	.....	3487	21 32.2	+47 28	60	− 4	9.1	B3eq
375	235565	*3384*	21 34.3	+51 3	63	− 1	8.8	B2ne
376	206773	2374	21 39.3	+57 17	67	+ 3	7.0	Bone
377	207232	3430	21 42.4	+50 12	63	− 2	7.0	B8ne
378	207329	3144	21 43.1	+51 39	64	− 1	7.4	B2e
379	207757	*4673*	21 46.2	+12 9	38	−32	7.6v	Bep
380	208392	*2216*	21 50.9	+62 8	72	+ 6	7.1	B3ne
381	208682	1607	21 52.9	+64 52	73	+ 8	5.8	B3ne
382	235683	3211	21 55.6	+51 55	66	− 2	9.0	B3e
383	209296	2676	21 57.2	+56 14	69	+ 1	8.1	B(5)e
384	209409	o Aqr	21 58.1	− 2 38	26	−44	4.7	B6ne
385	210129	25 Peg	22 3.1	+21 13	48	−28	5.7	B8ne
386	212044	3341	22 16.4	+51 21	68	− 5	7.1	B2e
387	212076	31 Peg	22 16.6	+11 42	44	−37	4.9	B3e
388	212571	π Aqr	22 20.2	+ 0 52	35	−46	4.6	B1ne
389	213088	3213	22 23.9	+52 28	70	− 4	8.2	B8ne
390	214168	8 Lac	22 31.4	+39 7	64	−16	5.8	B3ne
391	214197	RZ Lac	22 31.6	+52 14	71	− 5	9 v	B0e
392	214748	ϵ PsA	22 35.1	−27 34	353	−62	4.2	B8ea
393	216057	2993	22 44.6	+53 53	73	− 4	6.1	B8ne
394	217050	*3985*	22 52.7	+48 9	72	−10	5.2	B3ne
395	217543	*4744*	22 56.3	+38 10	69	−20	6.4	B3ne
396	217891	β Psc	22 58.8	+ 3 17	48	−50	4.6	B5e
397	218393	4045	23 2.6	+49 40	74	− 9	6.8	Ave
398	220058	2942	23 15.7	+55 15	78	− 5	8.5	B(1)ne
399	220116	2724	23 16.1	+57 43	79	− 2	8.8	B5ne
400	.....	Comp R Aqr	23 38.6	−15 50	37	−71	9 v	Pec.
401	223387	3094	23 44.0	+56 40	82	− 5	9.2	B(0)ne
402	223501	2537	23 45.0	+61 39	84	0	8.2	B3e
403	223960	2636	23 48.9	+60 18	84	− 1	7.0	A0sea
404	224055	2562	23 49.7	+61 17	84	0	7.2	B2sea
405	224424	*2676*	23 52.7	+59 9	84	− 2	7.8	B0sea
406	224544	5012	23 53.7	+31 48	79	−29	6.4	B5ne
407	224559	4381	23 53.8	+45 52	82	−15	6.5	B3ne
408	225094	*2356*	23 58.3	+63 5	85	+ 1	6.3	B2sea
409	225095	*3103*	23 58.3	+55 0	84	− 7	7.6	B1e
410	225160	2585	23 58.9	+61 40	85	0	8.6	O8ea

TABLE II

STARS WITH PECULIAR SPECTRA HAVING DARK *TiO* BANDS AND BRIGHT λ 4686 (*He* II)

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	*l*	*b*	Mag.
411.....	.....	AX Per	1^h30^m0	$+53°45'$	97	− 8	*11.0*
412.....	117970	RW Hya	13 28.8	−24 53	284	+36	*10* v
413.....	143454	T CrB	15 55.3	+26 13	9	+47	Nova
414.....	162214	RS Oph	17 44.8	− 6 40	348	+ 9	Nova
415.....	.....	CI Cyg	19 46.5	+35 26	39	+ 4	*11.0*
416.....	221650	Z And	23 28.8	+48 16	78	−12	10 v

NOTES TO TABLES I AND II

The following notes, in addition to recording unpublished data, indicate the chief features of a few of the more interesting peculiar spectra.

MWC

1. H.D. 108. This is the only star in Table I in whose spectrum we have noticed emission at λλ 4634, 4640, and 4686. These bright lines are the features for which the Victoria observers have recently used the suffix "f." The bright hydrogen lines, however, are well marked and not greatly different from those found in certain Be stars. The classification symbol might be O6fe.
2. H.D. 144. Not previously announced. On a grating spectrogram (dispersion 66 A per millimeter) taken at Mount Wilson on September 18, 1932, *Hα* appears as an emission line of low intensity centrally superposed on broad absorption. A bright *Hα* had been suspected on an objective-prism plate taken September 20, 1925.
9. H.D. 5394, γ Cassiopeiae. Material published prior to 1915 given in reference 32 is omitted from Table I. A slit spectrogram taken at Lowell Observatory on November 27, 1912, and forwarded to us through the courtesy of Dr. V. M. Slipher shows well-marked bright lines at *Hβ*, *Hγ*, and *Hδ*. Dr. Dean B. McLaughlin writes that plates taken at the Observatory of the University of Michigan during the fall of 1932 show the violet emission components of *Hβ* and *Hγ* to be definitely more intense than the red components.
13. H.D. 9105. The bright lines seem to have disappeared since the Harvard observations were made.
16. H.D. 10516, φ Persei. Material published prior to 1913 given in reference 2 is omitted from Table I.
17. M.W. 101. The bright lines are extraordinarily intense and include forbidden lines of ionized iron as in η Carinae. The nebular line λ 4658 also is bright.
31. H.D. 13854. Not previously announced. On a grating spectrogram (dispersion 34 A per millimeter) taken at Mount Wilson on October 12, 1932, *Hα* appears as an emission line of low intensity centrally superposed on weak absorption.
32. H.D. 14134, Boss 519. The companion star H.D. 14143, B1s, probably has emission at *Hα*; a grating spectrogram (dispersion 34 A per millimeter) taken at Mount Wilson on October 13, 1932, shows an indistinct bright component, but we do not

NOTES TO TABLES I AND II—*Continued*

MWC

consider it sufficiently well marked to justify the inclusion of the star in the catalogue.

35. Companion to *o* Ceti (H.D. 14386). Irregular variable, magnitude 10–11. Approximately 0".8 from the long-period variable *o* Ceti; position angle 130°.

45. H.D. 14818, 10 Persei. Not previously announced. A bright *Hα* of low intensity was detected by O. C. Wilson, Jr., on one-prism slit spectrograms taken at Mount Wilson on September 19 and October 13, 1932. The observation was confirmed by a grating spectrogram (dispersion 34 A per millimeter) taken December 16, 1932.

49. H.D. 15472. The description by Adams and Joy in reference 55 refers to slit spectrograms taken at Mount Wilson on September 19, 22, and 25, 1915. The spectrum appears to be essentially the same on a low-dispersion plate taken August 29, 1923.

65. H.D. 20336, H.R. 985. Some doubt exists concerning the actual discoverer of bright lines in the spectrum of this star. W. W. Campbell's paper dated June 28, 1894 (undoubtedly a typographical error; 1895 probably is correct), printed in the *Astrophysical Journal* for October, 1895, gives a list of Be stars "possibly all, ... , up to January, 1895," with the statement that unless otherwise specified *Hβ* had been observed to be bright by the Harvard College observers. This star, B.D.+65°340, is in the list and is not otherwise specified, implying that *Hβ* was observed to be bright by Harvard prior to January, 1895. In *Harvard Annals*, **56,** 182 (Table IV), 1912, however, the discoverer is stated to be Espin, 1896 (*Astronomische Nachrichten*, **140,** 243, 1896). This reference gives Espin's observation as follows: "1895, Sept. 22. F bright?" A detailed account of Espin's observation, quoted by Lockyer (*Monthly Notices of the Royal Astronomical Society*, **91,** 225, 1930), shows Espin's discovery to have been independent, but does not explain the presence of the star on Campbell's observing program at an earlier date.

69. H.D. 22192, ψ Persei. The spectrograms from which Adams determined the radial velocity of this star (*Mt. Wilson Contr.*, No. 105; *Astrophysical Journal*, **42,** 172, 1915) were taken at Mount Wilson on January 10, 11, 16, 17, 1911, and October 20, 1912. *Hβ* is a distinct double bright line superposed on diffuse absorption. At *Hγ* the bright portions appear as fringes to a well-marked central core. In both lines the two bright components have approximately equal intensities. Their measured separations are: *Hβ*, 3.1 A; *Hγ*, 2.5 A.

73. H.D. 23480, Merope, 23 Tauri. On slit spectrograms taken at Mount Wilson on December 7, 1916, and February 28, 1917, *Hβ* appears as a diffuse absorption line on which there may be superposed two bright components of extremely low intensity.

74. H.D. 23630, Alcyone, η Tauri. On slit spectrograms taken at Mount Wilson on December 7, 1916, and February 28, 1917, *Hβ* appears as a broad absorption line within which incipient emission is barely visible. The emission may be double with components of nearly equal intensity.

75. H.D. 23862, Pleione, 28 Tauri. The bright lines seem to have disappeared since the time of the early Harvard observations.

NOTES TO TABLES I AND II—*Continued*

MWC

77. H.D. 24479. The absorption lines of hydrogen and helium are diffuse, but λ 4481 *Mg* II is much better defined.

78. H.D. 24534, X Persei. Variable of the R Coronae type. Magnitude 6–7. D. B. McLaughlin writes that a spectrogram taken at Ann Arbor 1932.8 shows $V/R=1.4$, indicating that the relative intensities of the emission components have been changing in the same direction since 1930.

81. H.D. 25940, c Persei. Moderately strong emission, possibly double but not clearly resolved, appears at $H\beta$ on slit spectrograms taken at Mount Wilson on January 7, 10, 19, 1911, and January 27, 1912. At $H\gamma$, emission of lower intensity is visible; on the last plate, which is the best of the series, it is clearly double, the separation being about 2.2 A.

84. M.W. 143. The bright lines of hydrogen are very intense, and in addition lines of neutral helium and ionized iron are bright.

93. H.D. 31293, AB Aurigae. Variable of the R Coronae type. Magnitude *7.2–8.4*. The cores of the hydrogen lines change their positions independently of the wings.

95. H.D. 32256. It is not certain that this object should be included in the *Catalogue*. Remark in the *Henry Draper Catalogue:* "The continuous spectrum is strong and several bright lines are distinctly seen, two of which are $H\beta$ and $H\gamma$. The spectrum may belong to the P Cygni Class."

96. H.D. 32343, 11 Camelopardalis. Narrow emission lines of considerable strength are present at $H\beta$ and $H\gamma$ on slit spectrograms taken at Mount Wilson on January 11, March 17, December 14, 1911; November 26, December 23, 1912; January 24, 1913; and March 9, 1914.

97. H.D. 32763. It is not certain that this object should be included in the *Catalogue*. Remark in the *Henry Draper Catalogue:* "This spectrum contains bright hydrogen lines, but the image is too faint and indistinct to determine its true nature."

98. H.D. 32991, 105 Tauri. $H\beta$ appears as a fairly narrow bright line of moderate intensity on slit spectrograms taken at Mount Wilson on February 11, March 6 and 7, 1914; January 2, December 21, 1915; and November 2, 1917. Incipient emission appears at $H\gamma$ on the best plates.

99. H.D. 33152. The bright lines are unusually narrow.

100. H.D. 33232. The spectrum is somewhat peculiar, and the type appears to vary. The cores of the hydrogen lines are strong and well defined; their displacements, which are correlated with the behavior of the bright components, appear to vary in a period of more than ten years. The star is under investigation at Mount Wilson.

102. H.D. 33540. See remark in *Harvard Bulletin*, No. 891, p. 4, quoted in a footnote to Table VII.

108. H.D. 35343, S Doradus. Irregular variable, magnitude *8.2–9.8*. In the Greater Magellanic Cloud; spectrum of the P Cygni type. Said by H. Shapley to be "probably the most luminous star now [March 18, 1925] known."

109. H.D. 35345. The bright hydrogen lines are unusually narrow and well defined.

114. H.D. 37115. Brighter component of A.D.S. 4202. The spectral type of the ninth-magnitude companion (P.A. 180°; Sep. 1″) is A0.

115. H.D. 37202, ζ Tauri. Bright lines were apparently first noticed by V. M. Slipher on slit spectrograms taken at the Lowell Observatory in 1912. Excellent nega-

NOTES TO TABLES I AND II—*Continued*

MWC

tives taken November 14 and 18, 1912, were forwarded to us through the courtesy of Dr. Slipher. Emission is plainly visible on the violet edge of $H\beta$, and less distinctly on the red edge. The violet edge of $H\gamma$ is faintly bright. It is well known that the ultra-violet members of the Balmer series are remarkably strong and well-defined dark lines. Thirty members of the series, including m = 32, have been measured by Miss Losh on spectrograms taken at Ann Arbor.

137. M.W. 229. The bright hydrogen lines are extraordinarily intense. The type is uncertain.

140. H.D. 45314. D3 (helium) is bright on a grating spectrogram (dispersion 66 A per millimeter) taken at Mount Wilson on January 7, 1933.

142. H.D. 45677. The spectrum is very peculiar and interesting. In addition to the lines of hydrogen and ionized iron (normal and forbidden), the nebular lines λ 4068 [*S* II] and λλ 6300, 6363 [*O* I] are bright.

143 } H.D. 45725, 7; β Monocerotis. The following approximate data concerning this
144 } well-known triple star are taken from Aitken's *Double Star Catalogue:*

	P.A.	Dist.	Mag.
AB	132°	7".3	5.0–5.5
BC	105	2.8	5.5–6.0

All observers agree that the spectra of the preceding and following components have emission lines, but some doubt exists in regard to the intermediate star, B, concerning which Frost, Barrett, and Struve (*Astrophysical Journal*, **64**, 24, 1926) say: "The hydrogen lines show two bright components of small intensity. The red component is stronger than the violet." O. Struve (*ibid.*, **73**, 98, 1931) says of bright $H\beta$, "Narrow double." Struve writes that both these notes refer to a plate taken by Professor Frost on November 13, 1905. D. B. McLaughlin (*Publications of the Observatory of the University of Michigan*, **4**, 183, 1932) says: "All three components of this visual triple are emission-line stars. . . . . When a spectrogram is being taken the separation of the images of the two fainter components, β^2 and β^3, on the slit of the spectrograph is approximately one-half the length of the slit as usually employed. As the position angle is close to 90°, it is possible to take the spectra of these two stars simultaneously, and with careful guiding and good seeing the spectra appear with little or no overlapping. Three such spectrograms have been taken, in October, 1928; October, 1930; and November, 1931. . . . . β^2 has double emission at $H\beta$ with a width of about 7.5 A and a central absorption line somewhat stronger and wider than that of β^3." The question is whether the bright lines which have been seen in the spectrum of the intermediate component are inherent in its light or whether the appearance has been caused by the partial overlapping of the light of the following component. A plate was taken at Mount Wilson on January 28, 1926, with the intermediate and following components on the slit according to the method mentioned by McLaughlin. $H\beta$ is definitely bright in the spectrum of the following component, but probably not in that of the intermediate component, although a very slight defect in the emulsion makes it impossible to be absolutely certain on this point. The hydrogen absorption seems considerably stronger in the intermediate component. At our request Dr. Struve and Dr. McLaughlin have reviewed their observations of this star. Both report their continued impression that the bright line in the intermediate com-

NOTES TO TABLES I AND II—*Continued*

MWC

ponent may be real, but agree that for the time being the star should be omitted from the catalogue.

The best test of the real existence of bright components at $H\beta$ is the presence of a stronger bright line at $H\alpha$, and here all available evidence is negative. Campbell (*Astrophysical Journal*, **2**, 180 n., 1895) says: "The intermediate star does not show a bright $H\alpha$ line." Merrill (*Lick Observatory Bulletin*, **7**, 169, 1913) says: "1912, October 6.02, no indication of a bright line at $H\alpha$." On a plate taken at Mount Wilson on October 14, 1932, with the grating spectrograph (dispersion 34 A per millimeter), $H\alpha$ is an absorption line near its normal position apparently without emission components.

The intermediate component has therefore been omitted from the catalogue pending confirmation of the evidence of bright lines in its spectrum. The type of the intermediate component is B2 or B3. The absorption lines of *H* and *He* are more intense than in the spectrum of the following component.

145. H.D. 45910. The structure of the hydrogen lines is very remarkable and is subject to variation as are also other features of the spectrum.

146. H.D. 45995, A.D.S. 5153. P.A. 4°; Sep. 16″. The spectral type of the eighth-magnitude companion is Ao.

147. H.D. 259431, B.D.+10°1172, N.G.C. 2247. Fourteen slit spectrograms taken at Mount Wilson during the years 1920–1928 are described by R. F. Sanford as follows: "The classification is uncertain. Neither helium nor λ 4481 of magnesium is at all conspicuous. Double bright lines appear at $H\beta$ and $H\gamma$, and there is some evidence of variability in their intensity."

151. R Monocerotis. In N.G.C. 2261. Irregular variable, possibly of the R Coronae type. Magnitude 9–14.

158. H.D. 50138. The violet component of the double bright $H\beta$ line exhibits extraordinary variations of intensity.

165. H.D. 53179, Z Canis Majoris. Variable of the R Coronae type. Magnitude 8.4–11.5. The behavior of this spectrum, which has numerous lines of iron and titanium, resembles, in a measure, that of the "iron star," XX Ophiuchi, H.D. 161114.

166. H.D. 53367. A bright line of low intensity is seen at $H\beta$ on slit spectrograms taken at Mount Wilson on December 29 and 30, 1920, and February 26, 1921.

169. H.D. 55271, A.D.S. 5863. P.A. 233°; Sep. 13″. The spectral type of the eighth-magnitude companion is Ao.

170. H.D. 56014, 27 Canis Majoris. O. Struve has shown that if the displacements of dark lines are caused by orbital motion, the minimum total mass of the whole system is approximately two thousand times the mass of the sun. Referring to three slit spectrograms of the blue-violet region taken at Mount Wilson on December 7 and 8, 1927, R. F Sanford says: "Emission, if present, consists of very weak red components." On a grating spectrogram (dispersion 34 A per millimeter) taken at Mount Wilson on December 17, 1932, the dark core of $H\alpha$ has a positive displacement. Conspicuous emission occurs on its violet side; on the other side the emission is much less intense.

173. H.D. 57150, v^1 Puppis. A slit spectrogram taken at Mount Wilson on October 30, 1922, shows fairly narrow bright lines diminishing in intensity from $H\beta$ to $H\epsilon$.

NOTES TO TABLES I AND II—*Continued*

MWC

177. H.D. 58343. Dr. F. C. Jordan writes that bright lines were first photographed at Allegheny Observatory in 1908. Fairly strong lines were seen at $H\beta$ and $H\gamma$ on slit spectrograms taken December 28, 1908; March 1, 5, 15, 1910; December 28, 1911; February 23, December 12, 1912; February 21, 1914. On some of these plates bright $H\delta$ and $H\epsilon$ also appeared. On January 27, 1912, however, the emission appeared to have been weaker, as it was then barely visible, although the exposure was moderately strong. On a slit spectrogram taken at Lick Observatory on November 29, 1912, emission at $H\alpha$ and $H\beta$ was well marked. Slit spectrograms taken at Mount Wilson on December 23, 1910; January 19, February 11, 1911; and December 26, 1912, show $H\beta$ and $H\gamma$ as conspicuous narrow bright lines superposed on broad absorption.

178. H.D. 58715, β Canis Minoris. $H\alpha$ is a conspicuous double bright line on grating spectrograms taken at Mount Wilson on February 15, 1930, and March 24, 1932.

197. H.D. 83953, I Hydrae. A bright line of moderate intensity is seen at $H\beta$ on a slit spectrogram taken at Mount Wilson on February 22, 1926.

214. H.D. 93308, η Carinae, Nova Carinae No. 1. The spectrum is very peculiar and interesting. The forbidden lines of ionized iron are very strong.

221. H.D. 107348, ζ Corvi. Not previously announced. Mr. O. C. Wilson, Jr., found a bright $H\alpha$ line on a one-prism slit spectrogram taken at Mount Wilson on May 12, 1932. Re-examination of a slit spectrogram taken June 1, 1912, shows a weak double bright line at $H\beta$.

229. H.D. 120324, μ Centauri. This star offers a most striking example of changing intensities of the hydrogen lines. R. H. Curtiss summarized the early observations as follows: "Apparently the strong emission of the nineties was distinct in 1904, evanescent in 1912, and non-existent in 1918." For several years after 1918 the bright lines were absent or of low intensity. Grating spectrograms taken at Mount Wilson on June 20, 1929; February 14, 1930; May 6, 1931; and February 27, 1932, show $H\alpha$ to be a conspicuous bright line, apparently gradually increasing in intensity.

237. H.D. 138749, θ Coronae Borealis. A grating spectrogram (dispersion 34 A per millimeter) taken at Mount Wilson on May 5, 1931, shows $H\alpha$ as a wide, diffuse absorption line. One-prism slit spectrograms taken at Mount Wilson by O. C. Wilson, Jr., on February 26 and June 13, 1932, show $H\alpha$ and $H\beta$ as strong absorption lines without visible emission.

239. H.D. 142983. The spectrum is peculiar and may vary. The structure of $H\alpha$ is interesting. Remark in the *Henry Draper Catalogue:* "The spectrum is peculiar in combining sharply defined hydrogen lines with wide and ill-defined helium lines. In this respect it resembles the spectrum of ϵ Capricorni."

241. H.D. 148184, χ Ophiuchi. The bright hydrogen lines are unusually narrow.

251. H.D. 154450. The bright hydrogen lines are unusually narrow and sharp.

263. H.D. 160095. This star may belong to that small group of Be stars which have α Cygni lines of variable intensity.

265. RT Serpentis. The spectrum of this nova-like variable has undergone extraordinary changes. In 1928 the forbidden lines of ionized iron were outstanding.

266. H.D. 160529. On the slit spectrograms taken at Mount Wilson the α Cygni lines are very strong.

NOTES TO TABLES I AND II—*Continued*

MWC

269. H.D. 161114, XX Ophiuchi. Variable of the R Coronae type. Magnitude *9.6–10.7*. The "iron star." The spectrum is peculiar and variable.

270. M.W. 174. The bright hydrogen lines are very intense.

272. M.W. 54, D.M.$-27°11944$. The lines exhibit the P Cygni characteristics in a very marked degree. The spectrum may be said to be intermediate between that of P Cygni and of a typical nova.

275. H.D. 163296. The cores of the hydrogen lines probably change their positions independently of the wings. The behavior apparently resembles that of H.D. 31293.

279. H.D. 164447. Not previously announced. A description of the spectrum will be published by G. Shajn in the *Circulars* of the Poulkovo Observatory.

280. H.D. 164906. In N.G.C. 6523 = M 8.

292. H.D. 168957. Slit spectrograms taken at Victoria on May 20, 1924, and April 24, 1925, and forwarded to us through the courtesy of Dr. J. A. Pearce show a narrow emission component of low intensity superposed nearly centrally on broad absorption at $H\beta$ and $H\gamma$. Dr. C. S. Beals writes that a plate taken by him on May 14, 1932, shows no indication of emission lines.

293. H.D. 169226. On a slit spectrogram taken at Mount Wilson on July 20, 1924, the line $H\beta$ appears to be of the P Cygni type.

294. H.D. 169454. The spectrum is notable for the prominence of dark lines of ionized oxygen. $H\alpha$ and $H\beta$ have, to a certain extent, the P Cygni characteristics. They may be variable in structure and intensity.

295. H.D. 169515, RY Scuti. Irregular variable. Magnitude *8.3–9.2*. The nebular line λ 4658 is bright.

300. M.W. 182. The forbidden lines of neutral oxygen $\lambda\lambda$ 6300, 6363 are bright.

303. H.D. 172694. The absorption spectrum is peculiar. The dark line λ 4471 *He* is unusually strong and well defined.

306. H.D. 174638, 9; β Lyrae. Eclipsing variable. Period 12.9 days. Magnitude 3.4–4.1. The spectrum is very peculiar and varies with the light-phase. Material published prior to 1911 given in reference 1 is omitted from Table I.

311. H.D. 178175. Forty-nine slit spectrograms taken at Mount Wilson during the years 1912–1929 are described by R. F. Sanford as follows: "Double emission components of the hydrogen lines vary from slightly stronger than the adjacent continuous spectrum to an intensity so low that the effect upon the absorption line is nearly negligible."

313. H.D. 181615, 6; υ Sagittarii. The spectrum is peculiar and variable.

314. M.W. 74, B.D.$+14°3887$. The bright hydrogen lines are unusually strong and narrow. Eight or ten enhanced lines of iron are bright.

315. M.W. 187. The bright hydrogen lines are very intense. The decrement in intensity from $H\beta$ to $H\zeta$ appears to be unusually small.

316. M.W. 75, B.D.$+22°3687$, βG.C. 9287. P.A. 138°, Sep. 16″. The spectral type of the tenth-magnitude companion is A(0).

317. H.D. 183143. This star is remarkable for its large color excess.

319. H.D. 184279. The dark line λ 4471 *He* is unusually intense.

325. H.D. 190073. This star has a most peculiar spectrum. The sodium lines D1,2 are bright, and the structure of the H and K lines is very remarkable.

NOTES TO TABLES I AND II—*Continued*

MWC

331. H.D. 192044, 20 Vulpeculae. On slit spectrograms taken at Mount Wilson on July 7, 10, 13, 18 and October 6, 7, 1911, $H\beta$ consists of a broad absorption line on which are symmetrically superposed two faint emission components (separation approximately 3.7 A) of nearly equal intensity. Their distinctness varies on different plates and the changes may be intrinsic.

335. H.D. 192954. Not previously announced. $H\alpha$ was suspected to be bright on an objective-prism photograph taken at Mount Wilson on July 12, 1929. M. L. Humason noticed, independently, that $H\beta$ appeared to have weak bright edges on a slit spectrogram taken August 3, 1930. The presence of bright lines was definitely established by a slit spectrogram taken November 15, 1932, which shows $H\alpha$ as a strong bright line. The decrease from the intensity of emission at $H\alpha$ to that at $H\beta$ is remarkably great. The absorption lines are well defined.

338. H.D. 193237, P Cygni, Nova Cygni 1600. In the spectrum of this star, which serves as a prototype for a group of peculiar spectra, strong bright lines in approximately their normal positions are accompanied by dark companions on their violet edges.

341. H.D. 193911, 25 Vulpeculae. Slit spectrograms taken at Mount Wilson on August 10, 16, 17, 1911; July 30, October 19, November 25, 1912; and August 23, 1921, show $H\beta$ as a fairly strong absorption line on which is centrally superposed a bright line of moderate intensity. On the best plates the bright line has the appearance of an unresolved double with components of nearly equal intensity.

347. H.D. 195592. The dark helium line λ 4471 is unusually strong.

349. M.W. 203. In addition to bright lines of hydrogen and neutral helium, the nebular line λ 4658 is bright.

350. H.D. 196712. A description of the spectrum will be published by G. Shajn in the *Circulars* of the Poulkovo Observatory.

351. H.D. 197345, α Cygni. $H\alpha$ consists of a displaced dark line with emission on the long wave-length edge. The normal position of $H\alpha$ lies between the effective centers of the bright and dark components. Articles referring to the presence of emission are the only ones included in the bibliography. O. Struve states that observations made at the Perkins Observatory in December, 1932, show the $H\alpha$ line in β Orionis, cB8, to be peculiar, apparently resembling the same line in α Cygni (*Astrophysical Journal*, **77**, 67, 1933).

352. H.D. 198183, λ Cygni. A slit spectrogram taken at Mount Wilson on September 20, 1926, shows $H\beta$ to be a broad absorption line with a narrow bright component of low intensity superposed nearly centrally. $H\gamma$, $H\delta$, and $H\epsilon$ appear wholly dark. On a grating spectrogram (dispersion 66 A per millimeter) taken August 1, 1928, $H\alpha$ is a clearly marked bright line, although of moderate intensity, superposed on broad weak absorption. Another grating plate (dispersion 34 A per millimeter) taken May 5, 1931, shows $H\alpha$ to be a weak absorption line without definite bright components. The intensity of the bright component is certainly less on the later date.

353. H.D. 198478, 55 Cygni. On a grating spectrogram (dispersion 34 A per millimeter) taken at Mount Wilson on August 18, 1932, $H\alpha$ appears as an emission line of very low intensity with a dark companion on its violet edge.

NOTES TO TABLES I AND II—*Continued*

MWC

358. H.D. 199478. Slit spectrograms taken at Mount Wilson on July 8, 1911; July 25, August 21, October 31, 1912; and October 13, 1930, show slight variations in the appearance of $H\beta$.

360. H.D. 200310, 60 Cygni. Slit spectrograms were taken at Mount Wilson on July 10, 1911; July 26, August 25, September 18, 1912; October 3, 1917. On the last plate, $H\beta$ has two bright components (separation 5.1 A) of low and nearly equal intensity. They may be faintly present on the first plate but cannot be seen on the 1912 plates.

361. H.D. 200775, N.G.C. 7023. About forty slit spectrograms taken at Mount Wilson during the years 1920–1929 are described by R. F. Sanford as follows: "$H\beta$ appears to have two emission components of approximately equal intensity. The profile of $H\gamma$ points to a similarity in its structure."

368. H.D. 203699. On slit spectrograms taken at Mount Wilson on September 26, October 23, November 16, 1912; October 18, 19, 1921, $H\beta$ is a rather narrow bright line superposed on broad absorption. $H\gamma$ is hazy as if partly neutralized by emission, but bright components are not clearly seen.

373. H.D. 205637, ϵ Capricorni. The spectrum is peculiar and variable.

379. H.D. 207757, B.D.+11°4673, AG Pegasi. Irregular variable. Magnitude 6.3–7.7. The spectrum is very peculiar and interesting. Prior to 1920 the helium lines were dark; since then they have been bright with dark borders on the violet edge. Lines of various elements exhibit variable displacements which have a common period of eight hundred days but differ in phase, amplitude, and "center-of-mass" velocity.

381. H.D. 208682. Slit spectrograms taken at Victoria on July 26, August 28, November 25, 1919, and forwarded to us through the courtesy of Dr. J. A. Pearce show at $H\beta$ two weak bright lines superposed on broad absorption. Traces of emission are visible at $H\gamma$ also. On slit spectrograms taken at Mount Wilson on August 5, 1922; August 18, September 20, October 22, November 20, 1923; July 21, September 14, 1926, the bright components are absent or extremely weak, and the dark hydrogen lines appear more intense than on the Victoria plates.

385. H.D. 210129, 25 Pegasi. Slit spectrograms taken at Mount Wilson on October 12, November 1, December 13, 1911, show $H\beta$ to be a bright line of moderate width and intensity (probably an unresolved double) superposed on wider absorption. Incipient emission is probably present within the broad absorption at $H\gamma$.

390. H.D. 214168, 8 Lacertae; northern and brighter component, A.D.S. 16095. P.A. 186°; Sep. 22″. The spectral type of the fainter component is B2; the dark lines are stronger and narrower than in the northern component. On slit spectrograms of the northern component taken at Mount Wilson on August 11, 14, 17 and October 7, 1911; September 20, 1926, ill-defined emission of low intensity is present at $H\beta$; $H\gamma$ is nearly neutral. Dr. Dean B. McLaughlin writes that two slit spectrograms taken at Ann Arbor 1932.8 show V/R to be 1.3, and that the change in the relative intensity of the emission components has been continuing in the same direction since 1930.

391. H.D. 214197, RZ Lacertae. Irregular variable. Magnitude 8.6–9.2. Near Nova Lacertae 1910. Not previously announced. Bright lines were discovered by R. F. Sanford on slit spectrograms taken at Mount Wilson. Six plates taken during the years 1926–1929 are described by Dr. Sanford as follows: "A weak emission line

NOTES TO TABLES I AND II—*Continued*

MWC

appears centrally upon the absorption line $H\beta$. Some plates also show similar structure for $H\gamma$."

397. H.D. 218393. The spectrum has α Cygni lines of variable intensity. Mr. W. E. Harper writes that 6 slit spectrograms were taken at Victoria between September 23, 1931, and October 1, 1932. The mean velocity from the hydrogen absorption, H and K, λ 4481, and enhanced lines, including some rather widely discordant values, is −18 km/sec.; from helium λ 4471, −110 km/sec. "Emission seems to be present for the hydrogen lines, largely the redward component."

400. Companion to R Aquarii (H.D. 222800). Irregular variable. Magnitude 8–10. The position of this star appears to be identical with that of the long-period variable R Aquarii. The spectrum is peculiar and variable to a remarkable extent.

403. H.D. 223960. On a grating spectrogram (dispersion 34 A per millimeter) taken at Mount Wilson on August 20, 1932, $H\alpha$ appears as a narrow dark line displaced toward the violet; emission is not clearly seen and is less intense than on October 12, 1929.

404. H.D. 224055. Classified Bo by Harvard, B8s by Victoria. Perhaps the spectrum changes.

405. H.D. 224424. Not previously announced. An emission line of low intensity is seen at $H\alpha$ on a grating spectrogram (dispersion 66 A per millimeter) taken at Mount Wilson on September 19, 1932.

406. H.D. 224544. $H\alpha$ is an intense bright line on a grating spectrogram (dispersion 34 A per millimeter) taken at Mount Wilson on September 16, 1932.

410. H.D. 225160. It is not certain that the characteristics of the Balmer lines are those typical of Be stars. They may resemble those of late O-type spectra in which bright lines of low intensity are seen at λλ 4634, 4640, 4686. As these bright lines are not definitely seen in this spectrum, however, the classification symbol "e" is used and the star is included in Table I.

BIBLIOGRAPHY

The bibliography lists references that give observational material concerning the objects in Tables I and II. Our intention has been to make it complete for spectroscopic observations; lists of data concerning magnitude, position, proper motion, and parallax have not been included. A few selected references to the light-curves of variable stars have, however, been added. Several references to the discovery of variable radial velocity were omitted because they are found in Moore's *Third Catalogue of Spectroscopic Binary Stars* (ref. 267). The tables and notes in the *Revised Harvard Photometry* and in the monumental *Henry Draper Catalogue* include data for many Be stars and should be consulted as a matter of course. These catalogues are mentioned at the beginning of the bibliography, but specific references to them are omitted from the key.

Publications included in the bibliography are arranged alphabetically either by author, by title of periodical, or, in case of observatory publications, by location of the observatory; under each publication the order of entries is chronological.

TABLE III

REFERENCES TO BE STARS

Before 1870	2	1900–1909	24
1870–1879	2	1910–1919	71
1880–1889	1	1920–1929	150
1890–1899	37	1930–1932	73

The total number of references to published material is 364. Two unnumbered references precede the 363 numbered items, while No. 49 refers to unpublished material. The increase during recent years in the frequency of appearance is shown by Table III.

KEY TO BIBLIOGRAPHY

The following section lists for each star of Tables I and II those items of the bibliography (p. 114) that contain information concerning its spectrum or light-curve. The numbers in bold-face type are the current numbers of the stars in the *Catalogue*, Tables I and II.

1 59, 275, 280, 295, 323, 354, 362 **2** 274, 275 **3** 295 **4** 59, 275, 280, 295, 339 **5** 295 **6** 70, 280, 295 **7** 95, 109, 110, 114, 140, 145, 150, 157, 158, 161, 166, 267, 270, 274, 275, 305, 307, 312, 361, 362 **8** 95, 145, 158, 239, 274, 275, 308, 361, 362 **9** 32, 38, 39, 40, 47, 87, 107, 117, 118, 145, 152, 155, 158, 161, 165, 167, 169, 176, 183, 201, 267, 270, 274, 275, 279, 280, 284, 295, 302, 310, 313, 316, 321, 324, 325, 326, 329, 331, 337, 343, 353, 362 **10** 295 **11** 295 **12** 59, 275, 280, 295, 362 **13** 66, 275, 280, 295, 323, 354, 361, 362 **14** 63, 280, 295 **15** 295 **16** 2, 38, 40, 43, 47, 49, 87, 109, 111, 112, 145, 155, 161, 165, 180, 183, 257, 267, 270, 274, 275, 280, 284, 295, 310, 324, 326, 327, 334, 341, 353, 362 **17** 295 **18** 295 **19** 63, 280, 295 **20** 295 **21** 275, 295, 362 **22** 295 **23** 295 **24** 295 **25** 295 **26** 59, 280, 295 **27** 295 **28** 295 **29** 295 **30** 295 **31** 50, 275 **32** 50, 275, 295, 361, 362 **33** 295 **34** 295 **35** 12, 13, 57, 60, 73, 76, 77, 161, 192, 282, 284, 291 **36** 85 **37** 230 **38** 85 **39** 85 **40** 85, 295 **41** 295 **42** 295 **43** 295 **44** 295 **45** 275, 338 **46** 295 **47** 295 **48** 230, 280, 295 **49** 55 **50** 295 **51** 295 **52** 295 **53** 295 **54** 295 **55** 295 **56** 295 **57** 295 **58** 295 **59** 295 **60** 295 **61** 58, 59, 275, 280, 295, 361, 362 **62** 295 **63** 295 **64** 295 **65** 7, 17, 20, 35, 38, 46, 47, 58, 106, 114, 128, 145, 155, 161, 165, 168, 172, 180, 239, 257, 267, 275, 280, 284, 295, 310, 312, 324, 326, 328, 334, 353, 362 **66** 295 **67** 284, 295 **68** 275, 295, 361, 362 **69** 31, 38, 47, 128, 155, 161, 165, 172, 180, 239, 240, 242, 257, 274, 275, 280, 284, 295, 310, 324, 326, 331, 353, 362 **70** 67, 280,

295 **71** 295 **72** 47, 134, 145, 155, 158, 172, 174, 183, 237, 238, 239, 240, 241, 251, 257, 270, 274, 275, 280, 324, 331, 362, 363 **73** 28, 47, 134, 145, 155, 158, 172, 174, 183, 237, 238, 239, 241, 251, 257, 274, 275, 280, 295, 324, 331, 362, 363 **74** 47, 128, 134, 145, 155, 174, 180, 183, 237, 238, 240, 241, 251, 257, 268, 269, 270, 274, 275, 280, 324, 331, 362, 363 **75** 4, 20, 39, 47, 52, 98, 122, 128, 145, 158, 172, 174, 175, 180, 183, 237, 242, 251, 257, 274, 275, 280, 363 **76** 295 **77** 95, 145, 158, 274, 275 **78** 17, 47, 106, 126, 128, 180, 275, 280, 295, 361, 362 **79** 295 **80** 67, 280, 295 **81** 28, 38, 47, 51, 109, 133, 145, 155, 158, 165, 178, 180, 222, 239, 257, 267, 270, 274, 275, 280, 292, 295, 306, 310, 312, 324, 331, 353, 362 **82** 295 **83** 230, 280, 295 **84** 295, 296 **85** 295 **86** 124, 128, 178, 180, 257, 274, 275, 362 **87** 295 **88** 61, 275, 280, 290, 295, 361, 362 **89** 275, 361, 362 **90** 295 **91** 295 **92** 47, 59, 135, 139, 145, 155, 157, 158, 239, 267, 274, 275, 280, 300, 312, 323, 332, 361, 362 **93** 194, 233, 295 **94** 295 **95–96** 28, 38, 41, 47, 51, 145, 155, 157, 158, 161, 165, 178, 180, 219, 257, 274, 275, 276, 280, 284, 295, 310, 353, 362 **97** 180, 216 **98** 28, 47, 53, 55, 275, 295, 361, 362 **99** 61, 275, 280, 295, 362 **100** 61, 280, 295 **101** 63, 280, 295 **102** 195, 250 **103** 61, 275, 280, 295, 361, 362 **104** 275, 361, 362 **105** 180, 186, 195, 212 **106** 195 **107** 228, 275, 280, 295, 361, 362 **108** 180, 186, 195, 198, 212, 214, 235 **109** 228, 280, 284, 295 **110** 17, 20, 26, 45, 46, 47, 133, 145, 155, 161, 165, 178, 180, 221, 255, 257, 274, 275, 284, 295, 310, 312, 324, 326, 353, 361, 362 **111** 28, 47, 145, 155, 165, 178, 180, 224, 274, 275, 280, 295, 310, 361, 362 **112** 195 **113** 195 **114** 59, 280, 295 **115** 15, 17, 20, 27, 29, 40, 41, 43, 44, 47, 132, 136, 145, 155, 158, 161, 247, 267, 270, 274, 275, 280, 284, 292, 295, 301, 312, 322, 324, 326, 331, 347, 348, 352, 362, 363 **116** 295 **117** 8, 47, 142, 145, 155, 257, 267, 274, 275, 295, 309, 312, 362 **118** 61, 275, 280, 295, 361, 362 **119** 145, 164, 174, 175, 180, 211, 257, 274, 275, 362 **120** 295 **121** 180, 195, 216 **122** 61, 275, 280, 295, 361, 362 **123** 180, 186, 195, 212 **124** 228, 275, 280, 361, 362 **125** 67, 280 **126** 180, 186, 195, 212 **127** 63, 280, 295 **128** 63, 280 **129** 67, 280, 295 **130** 295 **131** 275, 361, 362 **132** 47, 49, 63, 109, 113, 145, 155, 157, 158, 267, 274, 275, 280, 295, 300, 307, 312, 338, 362 **133** 8, 28, 47, 100, 128, 145, 155, 161, 172, 180, 257, 274, 275, 280, 284, 295, 361, 362 **134** 271, 275, 295 **135** 63, 280 **136** 70, 275, 280, 295, 361, 362 **137** 295 **138** 28, 47, 145, 155, 178, 180, 218, 257, 274, 275, 295, 362 **139** 63, 280, 295 **140** 63, 267, 275, 280, 295, 354, 362 **141** 37, 47, 115, 137, 145, 155, 267, 275, 295, 304, 312, 324, 331, 362 **142** 78, 161, 180, 215, 275, 284, 288, 295, 337, 362 **143** 28, 31, 33, 38, 40, 47, 120, 128, 144, 145, 155, 161, 165, 171, 172, 180, 257, 274, 275, 280, 284, 295, 310, 353, 362 **144** 47, 128, 144, 145, 155, 180, 257, 274, 275, 312, 362 **145** 61, 71, 72, 215, 275, 280, 284, 295, 354, 356, 357, 360, 362 **146** 59, 267, 275, 280, 290, 295, 323, 354, 362 **147** 277, 279, 280, 295 **148** 295 **149** 295 **150** 145, 164, 274, 275, 295 **151** 246, 279, 284 **152** 8, 179, 180, 257, 274, 275, 295, 362 **153** 275, 361, 362 **154** 295 **155** 8, 127, 128, 161, 174, 175, 180, 203, 257, 274, 275, 295, 362 **156** 228, 275, 280, 295, 361, 362 **157** 295 **158** 61, 161, 275, 280, 291, 292, 295 **159** 63, 280, 295 **160** 275, 280, 295, 361, 362 **161** 125, 128, 180, 275, 280, 281, 284, 295, 361, 362 **162** 295 **163** 295 **164** 295 **165** 184, 226, 228, 233, 284, 295 **166** 275, 277, 279, 295, 361, 362 **167** 8, 174, 175, 180, 216, 257, 295 **168** 61, 275, 280, 295, 361, 362 **169** 61, 280, 295 **170** 3, 8, 127, 128, 145, 146, 147, 148, 151, 156, 158, 159, 160, 161, 174, 175, 180, 213, 257, 267, 272, 274, 275, 280, 295, 332, 362 **171** 8, 128, 145, 155, 158, 161, 164, 172, 174, 175, 180, 257, 267, 272, 273, 274, 275, 280,

284, 295, 362 **172** 67, 280 **173** 8, 121, 128, 174, 175, 180, 257, 274, 275, 280, 295, 362 **174** 295 **175** 228, 280, 295 **176** 275, 361, 362 **177** 8, 51, 257, 274, 275, 276, 280, 295, 362 **178** 37, 47, 144, 145, 155, 158, 240, 268, 269, 270, 274, 275, 280, 312, 331 **179** 161, 178, 180, 203, 219, 257, 274, 275, 280, 295, 362 **180** 67, 280, 295 **181** 67, 280, 295 **182** 67, 280, 295 **183** 79, 228, 271, 275, 280, 295 **184** 267, 275, 295, 323, 354, 362 **185** 67, 280, 295 **186** 8, 174, 175, 180, 211, 257, 274, 275, 295, 362 **187** 295 **188** 295 **189** 295 **190** 228, 275, 280, 284, 295, 361, 362 **191** 295 **192** 8, 121, 128, 161, 174, 175, 180, 257, 274, 275, 280, 284, 295, 362 **193** 174, 180, 217 **194** 229 **195** 83, 274, 275, 362 **196** 8, 11, 174, 175, 180, 211, 274, 275, 362 **197** 178, 180, 219, 257, 274, 275, 362 **198** 226 **199** 180, 217 **200** 184, 225 **201** 3, 8, 39, 174, 175, 180, 215, 232, 274, 275, 362 **202** 180, 216 **203** 202 **204** 179, 180 **205** 145, 178, 275, 295 **206** 231 **207** 202 **208** 8, 11, 39, 105, 174, 175, 180, 232, 241, 274, 275, 362 **209** 202 **210** 202 **211** 174, 202, 271, 274, 275, 362 **212** 180, 215 **213** 202 **214** 24, 82, 88, 174, 181, 182, 187, 200, 261, 264, 274, 275, 284, 287, 318, 319, 320, 336, 337, 345, 346, 351, 359, 360 **215** 174, 180, 186, 209 **216** 121, 174, 180, 186 **217** 202 **218** 83, 174, 274, 275, 362 **219** 84, 99, 128, 161, 174, 175, 180, 203, 241, 242, 274, 275, 352, 362 **220** 232 **221** 274, 275 **222** 9, 17, 18, 20, 38, 42, 46, 47, 108, 109, 128, 145, 155, 158, 162, 172, 180, 203, 239, 240, 242, 257, 259, 267, 269, 270, 274, 275, 280, 308, 312, 324, 331, 332, 353, 355, 362 **223** 262, 274, 275 **224** 11, 179, 180, 191, 222, 271, 275 **225** 174, 175, 180, 211, 274, 275, 362 **226** 101, 174, 175, 180, 271, 275 **227** 231 **228** 180, 222 **229** 8, 11, 39, 91, 99, 128, 161, 174, 175, 176, 180, 182, 205, 231, 241, 242, 248, 273, 274, 275, 280, 284, 337, 349, 350, 352, 362 **230** 8, 100, 128, 174, 175, 180, 271, 275 **231** 174, 175, 180, 211, 241, 274, 275, 362 **232** 3, 8, 100, 128, 174, 175, 180, 216, 249, 254, 267, 273, 274, 275, 280, 362 **233** 202, 223 **234** 202 **235** 3, 161, 174, 175, 180, 203, 216, 271, 275 **236** 180, 186, 215 **237** 145, 257, 259, 274, 275, 312, 333, 361, 362 **238** 180, 216, 232 **239** 145, 164, 178, 274, 275, 292, 295, 362 **240** 179, 180, 222 **241** 28, 47, 87, 102, 128, 145, 155, 158, 161, 165, 178, 180, 219, 253, 257, 267, 270, 274, 275, 276, 284, 295, 310, 353, 362 **242** 232 **243** 174, 175, 180, 210, 274, 275, 280, 362 **244** 202 **245** 228 **246** 232 **247** 295 **248** 202 **249** 67, 280, 295 **250** 68, 280, 295 **251** 68, 280, 295 **252** 179, 180, 222, 274, 275, 280, 295, 362 **253** 180, 226, 280, 295 **254** 271, 275, 295 **255** 68, 280, 295 **256** 295 **257** 202 **258** 161, 179, 180, 203, 222, 274, 275, 362 **259** 179, 180, 222 **260** 295 **261** 174, 175, 180, 210, 241, 267, 274, 275, 362 **262** 295 **263** 70, 280, 290, 295 **264** 68, 280, 295 **265** 74, 90, 92, 267, 275, 278 **266** 295 **267** 104, 181, 186, 209, 232 **268** 68, 280, 295 **269** 75, 81, 119, 180, 207, 224, 234, 236, 280, 284, 293, 295 **270** 295 **271** 68, 280, 295 **272** 68, 196, 280, 281, 284, 295 **273** 295 **274** 70, 161, 275, 280, 286, 295, 362 **275** 280, 290, 295 **276** 70, 280, 295 **277** 68, 280, 295 **278** 83, 144, 145, 274, 275, 309, 312, 361, 362 **279–280** 70, 280, 295 **281** 295 **282** 295 **283** 295 **284** 68, 280, 295 **285** 280, 295 **286** 280, 295 **287** 295 **288** 129, 181, 186, 232, 280, 295 **289** 295 **290** 68, 280, 295 **291** 70, 280, 295 **292** 275, 361, 362 **293** 280, 295 **294** 70, 280, 290, 295 **295** 65, 69, 70, 280, 285, 295 **296** 70, 280, 295 **297** 295 **298** 280, 295 **299** 180, 209, 259, 280, 295 **300** 93, 295 **301** 295 **302** 295 **303** 280, 290, 295 **304** 180, 211, 280, 295 **305** 280, 295 **306** 1, 16, 19, 22, 30, 47, 49, 143, 161, 170,

267, 275, 280, 303, 312, 316, 329 **307** 295 **308** 275, 280, 295, 361, 362 **309** 295 **310** 275, 361, 362 **311** 83, 274, 275, 295, 362 **312** 280, 290, 295 **313** 3, 5, 10, 23, 47, 49, 103, 128, 130, 145, 172, 178, 180, 199, 257, 259, 263, 267, 274, 280, 295, 311, 315, 329, 332, 338, 356, 357, 358 **314** 280, 284, 295 **315** 295 **316** 275, 280, 295, 362 **317** 275, 280, 290, 295, 361, 362 **318** 275, 295, 361, 362 **319** 275, 295, 361, 362 **320** 295 **321** 280, 295 **322** 275, 280, 295, 361, 362 **323** 274, 275, 361, 362 **324** 295 **325** 295, 297, 351 **326** 267, 275, 295, 362 **327** 280, 295 **328** 229, 280, 284, 295 **329** 7, 17, 20, 21, 38, 47, 48, 145, 155, 158, 178, 180, 221, 239, 257, 267, 274, 275, 280, 295, 324, 353, 362 **330** 295 **331** 47, 51, 257, 267, 275, 276, 295 **332** 275, 280, 295, 361, 362 **333** 280, 295 **334** 295 **335–336** 275, 280, 295, 361, 362 **337** 295 **338** 4, 6, 25, 40, 47, 49, 52, 71, 87, 116, 123, 128, 131, 138, 149, 158, 163, 172, 173, 180, 186, 187, 204, 206, 239, 243, 252, 256, 260, 270, 275, 280, 292, 295, 299, 312, 324, 342, 352, 357, 360, 361, 362 **339** 231, 280, 295 **340** 295 **341** 47, 51, 259, 274, 275, 276, 295 **342** 295 **343** 267, 275, 295, 361, 362 **344** 295 **345** 275, 295, 361, 362 **346** 280, 290, 295 **347** 275, 295, 361, 362 **348** 295 **349** 295 **350** 314 **351** 176, 258, 265, 266, 267, 274 **352** 28, 47, 80, 145, 155, 239, 274, 275, 295, 361, 362 **353** 145, 157, 158, 239, 267, 274, 275, 295, 309, 340, 362 **354** 280, 295 **355** 295 **356** 59, 275, 280, 295 **357** 181, 218, 231, 275, 280, 295, 361, 362 **358** 145, 155, 157, 275, 295 **359** 7, 20, 34, 38, 39, 46, 47, 87, 109, 145, 155, 178, 180, 219, 239, 257, 267, 270, 274, 275, 295, 324, 330, 331, 338, 353, 361, 362 **360** 145, 155, 161, 274, 275, 361, 362 **361** 54, 56, 275, 279, 280, 295, 361, 362 **362** 295 **363** 275, 295, 361, 362 **364** 17, 20, 47, 49, 103, 109, 128, 145, 155, 161, 165, 172, 180, 203, 239, 257, 274, 275, 280, 295, 309, 310, 312, 324, 331, 362 **365** 74, 267, 275, 280, 283, 295, 361, 362 **366** 230, 275, 280, 295, 361, 362 **367** 47, 114, 145, 155, 165, 178, 180, 218, 257, 267, 274, 275, 280, 295, 310, 361, 362 **368** 53, 275, 295, 361, 362 **369** 275, 295, 361, 362 **370** 295 **371** 275, 361, 362 **372** 295 **373** 3, 47, 145, 155, 161, 174, 180, 245, 257, 259, 267, 274, 275, 362 **374** 295 **375** 295 **376** 226, 275, 280, 295, 361, 362 **377** 280, 295 **378** 275, 361, 362 **379** 36, 40, 116, 126, 128, 180, 186, 189, 275, 280, 284, 289, 294, 295, 337, 360, 362 **380** 158, 275, 295, 361, 362 **381** 114, 275, 362 **382** 295 **383** 295 **384** 17, 20, 47, 145, 155, 161, 178, 239, 240, 257, 274, 275, 280, 295, 310, 324, 331, 353, 361, 362 **385** 28, 47, 267, 275, 276 **386** 275, 280, 295, 361, 362 **387** 8, 28, 47, 145, 155, 157, 161, 165, 178, 180, 221, 239, 257, 274, 275, 280, 295, 310, 324, 331, 353, 362 **388** 8, 17, 20, 26, 38, 45, 47, 128, 145, 153, 154, 155, 158, 161, 172, 173, 180, 239, 242, 257, 274, 275, 280, 284, 312, 324, 326, 331, 352, 353, 361, 362 **389** 295 **390** 28, 47, 51, 145, 155, 178, 180, 184 257, 267, 275, 276, 295, 361, 362 **391–392** 59, 155, 274, 275, 280 **393** 295, 335, 338 **394** 39, 47, 141, 145, 267, 274, 275, 280, 295, 338, 361, 362 **395** 275, 361, 362 **396** 8, 28, 38, 47, 52, 58, 133, 145, 155, 161, 165, 178, 180, 239, 240, 257, 274, 275, 280, 284, 309, 310, 312, 324, 331, 353, 361, 362 **397** 290, 295 **398** 295 **399** 295 **400** 86, 284 **401** 295 **402** 295 **403** 295 **404** 275, 295, 361, 362 **405–406** 275, 333, 338, 361, 362 **407** 275, 280, 295, 361, 362 **408** 275, 295, 361, 362 **409** 178, 180, 218, 280, 284, 295 **410** 295 **411** 94, 208, 295, 296 **412** 94, 197, 296 **413** 62, 64, 96, 177, 187, 188, 244, 317, 344 **414** 89, 177, 185, 188, 217, 220 **415** 94, 190, 295, 296 **416** 14, 97, 185, 193, 227, 284, 337, 359

REFERENCES TO Be STARS

General Catalogues

Revised Harvard Photometry: Harvard College Observatory Annals, **50**, 1908.
Henry Draper Catalogue: Harvard College Observatory Annals, **91–100**, 1918——.

Allegheny Observatory, Publications

Ref.
1. CURTISS, R. H. On the Photographic Spectrum of β Lyrae. **2**, 73, 1912.
2. JORDAN, F. C. Spectrographic Observations of ϕ Persei. **3**, 31, 1916.

American Astronomical Society, Publications

3. CANNON, A. J. Variations of the Bright Hydrogen Lines in Stellar Spectra. **1**, 216, 1910; also *Science*, **21**, 414, 1905.
4. FROST, E. B. Observations of Radial Velocities. **1**, 243, 1910; also *Science*, **23**, 449, 1906.
5. ———. Spectrographic Observations. **1**, 308, 1910; also *Science*, **28**, 853, 1908.
6. CURTISS, R. H. Spectroscopic Notes from the Detroit Observatory. **3**, 5, 1918; also *Pop. Astr.*, **22**, 133, 1914.
7. ———. Some Structure Variations in Hydrogen Emission Lines in Spectra of Class B. **3**, 198, 1918; also *Pop. Astr.*, **24**, 659, 1916.
8. PERRINE, C. D. Changes in the Spectra of Some Early Type Stars Showing Hydrogen Emission. **4**, 38, 1923; also *Pop. Astr.*, **27**, 90, 1919.
9. BAKER, R. H. The Association of Hydrogen Lines with the "Invariable" K Line in the Spectrum of κ Draconis. **4**, 206, 1923; also *Pop. Astr.*, **29**, 146, 1921.
10. MAURY, A. C. Preliminary Note on υ Sagittarii. **4**, 273, 1923; also *Pop. Astr.*, **29**, 636, 1921.
11. CANNON, A. J. Recent Spectroscopic Results. **5**, 6, 1927; also *Pop. Astr.*, **31**, 188, 1923.
12. JOY, A. H. The Spectrum of o Ceti at Minimum. **5**, 14, 1927; also *Pop. Astr.*, **31**, 237, 1923.
13. ———. Radial Velocity Measurements of the Spectrum of o Ceti. **5**, 64, 1927; also *Pop. Astr.*, **31**, 645, 1923.
14. PLASKETT, H. H. A Possible Origin of the Nebular Lines. **5**, 77, 1927; also *Pop. Astr.*, **31**, 658, 1923.
15. LOSH, H. M. The Spectrum of ζ Tauri. **5**, 175, 1927; also *Pop. Astr.*, **32**, 557, 1924.
16. MAURY, A. C. Some Peculiarities in the Spectrum of β Lyrae. **5**, 177, 1927; also *Pop. Astr.*, **32**, 559, 1924.
17. CURTISS, R. H. Studies of Spectrum Variables of Class Be. **5**, 284, 1927; also *Pop. Astr.*, **33**, 537, 1925.
18. STRUVE, OTTO. Changes in the Bright Lines of Hydrogen in 5 κ Draconis. **5**, 294, 1927; also *Pop. Astr.*, **33**, 596, 1925.

Ref.

19. MAURY, A. C. Variable Hydrogen and Helium Lines in the Spectrum of β Lyrae. **5,** 394, 1927; also *Pop. Astr.*, **34,** 625, 1926.
20. CURTISS, R. H. Spectrum Variables of Class Be. **6,** 258, 1929; also *Pop. Astr.*, **37,** 578, 1929.
21. LOSH, H. M. Velocity Studies of b^2 28 Cygni. **6,** 267, 1931; also *Pop. Astr.*, **38,** 25, 1930.
22. MCLAUGHLIN, L. H. A Note on the Emission Lines in β Lyrae. **6,** 272, 1931; also *Pop. Astr.*, **38,** 30, 1930.
23. SEYDEL, F. L. A Study of the Spectrum and Orbit of Upsilon Sagittarii. **6,** 278, 1931; also *Pop. Astr.*, **38,** 92, 1930.
24. BOK, B. J. The Spectrum of η Carinae. **6,** 337, 1931; also *Pop. Astr.*, **38,** 399, 1930.
25. WILLIAMS, W. J. The Spectrum of P Cygni. **6,** 377, 1931.
26. MCLAUGHLIN, D. B. Characteristics of Class Be Spectrum Variables. **7,** 31, 1931.
27. FATH, E. A. Report from Goodsell Observatory. **7,** 61, 1931.
28. MCLAUGHLIN, D. B. Fourteen New Be Spectrum Variables. **7,** 93, 1932.

Amsterdam, K. Akademie van Wentenschappen, Proceedings

29. PANNEKOEK, A. The Variability of the Pole Star. **15,** 1192, 1913 n.; also *Verslag*, **21,** 1116, 1913.

Ann Arbor, University of Michigan, Publications

30. CURTISS, R. H. A Determination of the Visual Light Curve of Beta Lyrae. **1,** 87, 1915.
31. MERRILL, P. W. The Spectrum and Radial Velocity of ψ Persei and of the Brightest Component of β Monocerotis. **1,** 136, 1915.
32. CURTISS, R. H. The Spectrum of γ Cassiopeiae. **2,** 1, 1916.
33. ———. *Ibid.*, Plate C and p. 182.
34. ———. Changes in the Spectrum of f^1 Cygni. **2,** 36, 1916.
35. ———. Changes in the Spectrum of H.R. 985. **2,** 39, 1916.
36. MERRILL, P. W. A Spectrum of the P Cygni Type. **2,** 71, 1916.
37. ———. Discovery of Two Bright-Line Stars of Class B. **2,** 181, 1916.
38. CURTISS, R. H. Widths of Hydrogen and Metallic Emission Lines in Class B Stellar Spectra. **3,** 1, 1923.
39. ———. Studies of Class B Stellar Spectra Containing Emission Lines: Sixth Paper. **3,** 16, 1923.
40. ———. Some Bright Line Stellar Spectra. **3,** 256, 1923, and Plate B.
41. ———. Some Bright Line Stellar Spectra. **3,** 256, 1923, and Plate C.
42. BAKER, R. H. The Spectrum of κ Draconis. **3,** 29, 1923.
43. CURTISS, R. H. A Pictorial Study of the Spectrum of Nova Geminorum II. **3,** 254, 1923, and Plate I.
44. LOSH, H. M. The Spectrum of ζ Tauri. **4,** 1, 1931.

Ref.

45. McLaughlin, D. B. The Spectral Variations of 25 Orionis and 52 (π) Aquarii. **4,** 37, 1931.
46. Curtiss, R. H. Variations of Emission Lines in Three Be Spectra (prepared for publication by D. B. McLaughlin). **4,** 163, 1932.
47. McLaughlin, D. B. A Spectroscopic Survey of the Brighter Be Stars. **4,** 175, 1932.
48. Losh, H. M. The Spectrum of b² 28 Cygni. **4,** 199, 1932.
49. Unpublished material.

Astronomical Journal

50. Adams, W. S., and van Maanen, Adriaan. A Group of Stars of Common Motion in the *h* and χ Persei Clusters. **27,** 187, 1911–1913.

Astronomical Society of the Pacific, Publications

51. Adams, W. S., and Lasby, J. B. Stars of the Orion Type with Bright Hydrogen Lines. **23,** 240, 1911.
52. Merrill, P. W. Helium Stars Having Bright Lines in Their Spectra. **24,** 181, 1912.
53. Adams, W. S. Three Stars with Bright Hydrogen Lines. **26,** 260, 1914.
54. Pease, F. G. Radial Velocities of Six Nebulae. **27,** 239, 1915.
55. Adams, W. S., and Joy, A. H. Two Stars with Bright Hydrogen Lines. **29,** 112, 1917.
56. Slipher, V. M. The Spectrum of N.G.C. 7023. **30,** 63, 1918.
57. Adams, W. S., and Joy, A. H. Changes in the Spectrum of *o* Ceti. **32,** 163, 1920.
58. Merrill, P. W. A Special Field of Usefulness for Small Telescopes in Photographing Stellar Spectra. **32,** 318, 1920, and Plate X.
59. Merrill, P. W., and Humason, M. L. Ten Stars of Class B Having the *Hα* Line Bright. **32,** 336, 1920.
60. Adams, W. S., and Joy, A. H. The Spectrum of *o* Ceti near Minimum of Light. **33,** 107, 1921.
61. Humason, M. L., and Merrill, P. W. Ten Stars of Class B Having the *Hα* Line Bright (2d list). **33,** 112, 1921.
62. Adams, W. S., and Joy, A. H. The Spectra of Three M-Type Stars with Bright Lines. **33,** 263, 1921.
63. Humason, M. L., and Merrill, P. W. Ten Stars of Class B Having the *Hα* Line Bright (3d list). **33,** 264, 1921.
64. Lundmark, Knut. The Spectrum of T Coronae. **33,** 271, 1921.
65. Merrill, P. W. The Nebular Line λ 4658 in Stellar Spectra. **34,** 134, 1922.
66. Merrill, P. W., and Humason, M. L. Disappearance of Bright Lines from the Spectrum of H.D. 9105. **34,** 180, 1922.
67. Humason, M. L., and Merrill, P. W. Ten Stars of Class B Having the *Hα* Line Bright (4th list). **34,** 223, 1922.

Ref.
68. ———. Ten Stars of Class B Having the *Hα* Line Bright (5th list). **34,** 294, 1922.
69. MERRILL, P. W. Note on the Spectrum of RY Scuti, B.D.−12°5045. **34,** 295, 1922.
70. HUMASON, M. L., and MERRILL, P. W. Ten Stars of Class B Having the *Hα* Line Bright (6th list). **34,** 351, 1922.
71. PLASKETT, J. S. A Remarkable Variable Spectrum. **35,** 145, 1923.
72. MERRILL, P. W. Notes on the Spectrum of H.D. 45910. **35,** 303, 1923.
73. AITKEN, R. G. Omicron Ceti a Visual Binary Star. **35,** 323, 1923.
74. ADAMS, W. S., and OTHERS. Ninety-seven Stars with Variable Velocity. **36,** 137, 1924.
75. MERRILL, P. W. The Iron Star H.D. 161114 (abstract). **36,** 225, 1924.
76. JOY, A. H. The Spectrum of the Close Companion of *o* Ceti. **36,** 290, 1924.
77. AITKEN, R. G. Measures of the Companion to Omicron Ceti. **36,** 296, 1924.
78. MERRILL, P. W. Unusual Bright Lines in the Spectrum of H.D. 45677. **37,** 163, 1925.
79. NEUBAUER, F. J. Note on the Spectrum of z Puppis, H.D. 60606. **37,** 329, 1925.
80. BALMER, H. F. The Bright Line Spectrum of λ Cygni. **37,** 330, 1925.
81. MERRILL, P. W. Titanium Lines in the Spectrum of the Iron Star, H.D. 161114. **38,** 45, 1926.
82. PERRINE, C. D. Nova Carinae, No. 1 (*η* Carinae, *η* Argus). **38,** 116, 1926.
83. BALMER, H. F. Four Stars of Spectral Type Be. **38,** 248, 1926.
84. ———. Note on the Spectrum of *δ* Centauri, H.D. 105435. **38,** 255, 1926.
85. TRUMPLER, R. J. B-Type Stars with Bright Hydrogen Lines in the Cluster χ Persei. **38,** 350, 1926.
86. MERRILL, P. W. Changes in the Spectrum of R Aquarii. **39,** 48, 1927.
87. YÜ, CH'ING-SUNG. Continuous Ultra-Violet Emission in Spectra of Class Be Stars and a Probable Continuous General Absorption in the Spectrum of P Cygni. **39,** 112, 1927.
88. MERRILL, P. W. New Iron Lines in Stellar Spectra. **39,** 363, 1927.
89. ADAMS, W. S., and OTHERS. Observations of Faint Spectra. **39,** 365, 1927.
90. ADAMS, W. S., and JOY, A. H. The Spectrum of RT Serpentis. **40,** 252, 1928.
91. MERRILL, P. W. Recent Observations of the Bright Hydrogen Lines in the Spectrum of *μ* Centauri. **41,** 270, 1929.
92. JOY, A. H. Nebular Lines in the Spectrum of RT Serpentis. **43,** 353, 1931.
93. MERRILL, P. W. Forbidden Lines of Neutral Oxygen in Stellar Spectra. **43,** 411, 1931.
94. MERRILL, P. W., and HUMASON, M. L. A Bright Line of Ionized Helium λ 4686 in Three Stellar Spectra with Titanium Bands. **44,** 56, 1932.
95. WILSON, O. C., JR. Three New Be Stars. **44,** 124, 1932.

Ref.

96. BERMAN, LOUIS. The Spectrum and Temperature of T Coronae (Nova 1866). **44,** 318, 1932.

97. HOGG, F. S. On the Presence of Titanium Oxide Bands in the Spectrum of Z Andromedae. **44,** 328, 1932.

Astronomische Nachrichten

98. PICKERING, E. C. Spectrum of Pleione. **123,** 95, 1890.

99. FLEMING, W. P. Spectra of δ and μ Centauri. **123,** 383, 1890.

100. ———. Stars Having Peculiar Spectra. **125,** 363, 1890.

101. ———. Stars Having Peculiar Spectra Including New Variables in Triangulum and Hydra. **126,** 117, 1891.

102. ———. Objects of Interest on Spectrum Plates and Two New Variable Stars in Perseus. **126,** 163, 1891.

103. ———. Stars Having Peculiar Spectra. **126,** 165, 1891.

104. ———. Stars Having Peculiar Spectra. **135,** 195, 1894.

105. ———. Stars Having Peculiar Spectra. **137,** 71, 1895.

106. ESPIN, T. E. Stars with Remarkable Spectra. **140,** 241, 1896.

107. BOTTLINGER, K. F. Über die Intensitätsverteilung innerhalb der Spektrallinien von Sternen. **195,** 117, 1913.

108. HNATEK, ADOLF. Beobachtung von Radialgeschwindigkeiten. **196,** 389, 1914.

109. LAU, H. E. Bemerkungen zur Revised Harvard Photometry. **196,** 425, 1914.

110. HNATEK, ADOLF. Beobachtungen von Radialgeschwindigkeiten. **197,** 185, 1914.

111. LUDENDORFF, H. Notiz über ϕ Persei. **197,** 219, 1914.

112. GUTHNIK, P. Übersicht über die Ergebnisse lichtelektrischer Messungen 1914–1917. **205,** 97, 1918.

113. LAU, H. E. Beobachtungen von χ^1 und χ^2 Orionis. **207,** 55, 1918; see also **208,** 143, 1919.

114. HNATEK, ADOLF. Beobachtungen von Radialgeschwindigkeiten am Wiener Coudéspektrographen. **210,** 245, 1920.

115. BERNEWITZ, E., und PAVEL, F. Duplizität von ν Geminorum. **211,** 13, 1920.

116. LUNDMARK, KNUT. Ein Neuer Veränderlicher vom P Cygni-Typus. **213,** 93, 1921.

117. STRUVE, OTTO. Über das Spektrum von γ Cassiopeiae. **246,** 105, 1932.

118. KOSIREV, N., und AMBARZUMIAN, V. Bemerkung über das Spektrum von γ Cassiopeiae. **246,** 171, 1932.

Astronomische Nachrichten, Beobachtungs-Zirkular

119. LAUSE, F. Veränderliche. **14,** 25, 1932.

Astronomy and Astrophysics

Ref.

120. FLEMING, W. P. Stars Having Peculiar Spectra. **11,** 418, 1892.
121. ———. Stars Having Peculiar Spectra. **11,** 765, 1892.
122. KEELER, J. E. Visual Observations of the Spectrum of β Lyrae. **12,** 352 n., 1893.
123. ———. Note on the Spectrum of P Cygni. **12,** 361, 1893.
124. FLEMING, W. P. Stars Having Peculiar Spectra. **12,** 546, 1893.
125. ———. Stars Having Peculiar Spectra. **12,** 810, 1893.
126. ———. Stars Having Peculiar Spectra. **13,** 501, 1894.

Astrophysical Journal[9]

127. FLEMING, W. P. Stars Having Peculiar Spectra. **1,** 411, 1895; also *A.N.*, **138,** 175, 1895.
128. CAMPBELL, W. W. Stars Whose Spectra Contain Both Bright and Dark Hydrogen Lines. **2,** 177, 1895.
129. FLEMING, W. P. Stars Having Peculiar Spectra. **2,** 354, 1895.
130. CAMPBELL, W. W. The Variable Velocities of β Capricorni and υ Sagittarii in the Line of Sight. **10,** 241, 1899.
131. BELOPOLSKY, ARISTARCH. Note on the Spectrum of P Cygni. **10,** 319, 1899; also *A.N.*, **151,** 37, 1900.
132. FROST, E. B., and ADAMS, W. S. Five Stars Whose Radial Velocities Vary. **17,** 150, 1903.
133. ———. Bright-Line Spectra. **18,** 389, 1903.
134. ADAMS, W. S. The Radial Velocities of the Brighter Stars in the Pleiades. **19,** 338, 1904.
135. FROST, E. B., and ADAMS, W. S. Four Stars Whose Radial Velocities Vary. **19,** 350, 1904.
136. ADAMS, W. S. The Orbit of the Spectroscopic Binary ζ Tauri. **22,** 115, 1905.
137. LEE, O. J. Measures on Nineteen New Spectroscopic Binaries. **32,** 300, 1910.
138. FROST, E. B. On the Spectrum of P Cygni. **35,** 286, 1912.
139. LEE, O. J. The Spectroscopic System 9 Camelopardalis. **37,** 1, 1913.
140. ———. Measures of Variable Radial Velocities of Stars. **39,** 39, 1914.
141. FROST, E. B. A Star with Disappearing Bright Lines. **49,** 61, 1919.
142. STRUVE, OTTO. Notes on Two Stars Having Variable Bright Lines. **58,** 138, 1923.
143. ROSSITER, R. A. On the Detection of an Effect of Rotation during Eclipse in the Velocity of the Brighter Component of Beta Lyrae and on the Constancy of Velocity of This System. **60,** 15, 1924.
144. STRUVE, OTTO. Twelve New Spectroscopic Binaries. **62,** 434, 1925.

[9] See also numerous articles listed under *Mount Wilson Observatory Contributions*.

Ref.

145. FROST, E. B., and OTHERS. Radial Velocities of 368 Helium Stars. **64,** 1, 1926.

146. STRUVE, OTTO. An Unusual Spectroscopic Binary (27 Canis Majoris). **65,** 273, 1927.

147. ———. On the Period of 27 Canis Majoris. **66,** 113, 1927.

148. ———. 27 Canis Majoris: The Question of Its Mass. **68,** 109, 1928.

149. ELVEY, C. T. Spectrophotometric Observations of P Cygni. **68,** 416, 1928.

150. STRUVE, OTTO. Variable Hydrogen Lines in 15 κ Cassiopeiae. **70,** 135, 1929.

151. ELVEY, C. T. The Contours of Helium Lines in Stellar Spectra. **70,** 141, 1929.

152. HIGGS, C. D. The Contours of Some Iron Lines in the Spectrum of 27 γ Cassiopeiae. **70,** 251, 1929.

153. ———. Note on the Variable Lines of Hydrogen in the Spectrum of 52 π Aquarii. **72,** 187, 1930.

154. LOCKYER, W. J. S. Note on the Variable Lines of Hydrogen in the Spectrum of 52 π Aquarii. **73,** 55, 1931.

155. STRUVE, OTTO. On the Origin of Bright Lines in Spectra of Stars of Class B. **73,** 94, 1931.

156. ———. Velocity-Curve and Spectral Variations of 27 Canis Majoris. **73,** 301, 1931.

157. ———. A Study of the Spectra of B Stars. **74,** 225, 1931.

158. ELVEY, C. T. Photo-electric Colors of Stars of Early Type. **74,** 298, 1931.

159. MCLAUGHLIN, D. B. A Note on the Mass of 27 Canis Majoris. **75,** 60, 1932.

160. STRUVE, OTTO. Note on 27 Canis Majoris. **75,** 158, 1932.

161. STRUVE, OTTO, and SWINGS, P. On the Interpretation of the Emission Lines in Stars of Early Spectral Class. **75,** 161, 1932.

162. JESSUP, M. K. Note on the Hydrogen Emission of κ Draconis. **76,** 75, 1932.

163. STRUVE, OTTO. 17 Leporis: A New Type of Spectrum Variable. **76,** 85, 1932.

164. ———. Notes on Be Stars. **76,** 210, 1932.

165. ———. On the Absorption Lines of Hydrogen in Be Stars. **76,** 309, 1932.

166. MARSHALL, R. K. A Note on the Occurrence of *O* III in Stellar Spectra. **76,** 317, 1932.

167. STRUVE, OTTO. The Width of Bright $H\alpha$ in γ Cassiopeiae. **77,** 66, 1933.

Berlin-Babelsberg, Universitätssternwarte, Veröffentlichungen

168. GUTHNICK, PAUL, und PRAGER, RICHARD. Photoelektrische Untersuchungen an Spektroskopischen Doppelsternen und an Planeten. **1,** Heft 1, 59, 1914.

Bulletin astronomique, mémoires et variétés

Ref.

169. BAILLAUD, JULES. Etude de spectrophotométrie stellaire. **4,** 275, 1923.

Cambridge, England, Solar Physics Observatory, Annals

170. BAXANDALL, F. E. The Spectrum of β Lyrae. **2,** 1, 1930.

Cambridge, Massachusetts, Harvard College Observatory, Annals

171. MAURY, A. C. Spectra of Bright Stars. **28,** 49, 1897.
172. ———. *Ibid.*, p. 94 (remarks); Tables XI and XII.
173. ———. *Ibid.*, pp. 122 ff. and Table XIV.
174. CANNON, A. J. Spectra of Bright Southern Stars. **28,** 162, 1901; Tables XVI and XVII and remarks (p. 175).
175. ———. *Ibid.*, pp. 227 ff. and Table XIX.
176. ———. *Ibid.*, Plate II.
177. ———. Second Catalogue of Variable Stars. **55,** 7, 1907; Table I and remarks.
178. ———. Classification of 1,477 Stars by Means of Their Photographic Spectra. **56,** 71, 1912; Tables I and IV and remarks (p. 104).
179. ———. Classification of 1688 Southern Stars by Means of Their Spectra. **56,** 117, 1912, Tables I and IV and remarks (p. 151).
180. FLEMING, W. P. Stars Having Peculiar Spectra. **56,** 181, 1912, and Table IV and remarks.
181. ———. *Ibid.*, p. 223; Table XIII and remarks.
182. ———. *Ibid.*, Plate III.
183. CANNON, A. J. Comparison of Objective Prism and Slit Spectrograms. **56,** 258, 1912; Table III and remarks.
184. ———. Spectra Having Bright Lines. **76,** 28, 1916, sentence preceding Table II.
185. ———. *Ibid.*, Table II and remarks.
186. ———. *Ibid.*, p. 31; Table III.
187. ———. *Ibid.*, p. 34; Table IV and remarks.
188. The Photographic Light Curves of 11 Novae. **84,** 121, 1920.

Cambridge, Massachusetts, Harvard College Observatory, Bulletins

189. Variations in Spectrum and Light of B.D.+11°4673. No. 762, 1922; also *Pop. Astr.*, **30,** 133, 1922.
190. Star Resembling RS Ophiuchi. No. 778, 1922.
191. Hydrogen Emission in Class B Spectrum. No. 779, 1922.
192. Omicron Ceti a Double Star. No. 792, 1923.
193. Z Andromedae, 232848. No. 797, 1924.
194. Irregular Variability of Class A Star. No. 798, 1924.
195. CANNON, A. J. Peculiar Spectra in the Large Magellanic Cloud. No. 801, 1924.
196. Test of C.D.M.−27°11944 for Variability. No. 807, 1924.

Ref.

197. RW Hydrae. No. 810, 1924.
198. SHAPLEY, HARLOW. S Doradus, a Super-giant Variable Star. No. 814, 1925.
199. MAURY, A. C. Note on the Secondary Spectrum and Mass Function of υ Sagittarii. No. 824, 1925.
200. DAVIDOVICH, PAUL. Comparison of the Spectra of η Carinae and Nova Pictoris 1925.4. No. 837, 1926.
201. PAYNE, C. H. Distribution of Intensity in Bright Hydrogen Lines of γ Cassiopeiae. No. 837, 1926.
202. ———. Twelve Stars of Class B Showing Emission Lines. No. 846, 8, 1927.
203. GERASIMOVIČ, B. P. Stars of Class B with Bright Lines of Ionized Iron. No. 851, 14, 1927.
204. ———. Changes in the Spectrum of P Cygni. No. 852, 16, 1927.
205. ———. On the Variation of the Spectrum of μ Centauri. No. 854, 1, 1928.
206. ———. On the Abnormally Low Temperature of P Cygni. No. 857, 15, 1928.
207. SHAPLEY, HARLOW, and WOODS, I. E. Observations of XX Ophiuchi. No. 868, 11, 1929.
208. LINDSAY, E. M. Note on a Peculiar Star. No. 888, 22, 1932.

Cambridge, Massachusetts, Harvard College Observatory, Circulars

209. Stars Having Peculiar Spectra. No. 9, 1896; also *A.N.*, **141,** 169, 1896.
210. Stars Having Peculiar Spectra. New Variable Stars in Crux and Cygnus. No. 12, 1896; also *A.N.*, **142,** 87, 1897.
211. Stars Having Peculiar Spectra. No. 17, 1897; also *A.N.*, **143,** 227, 1897.
212. Large Magellanic Cloud. No. 19, 1897; also *A.N.*, **145,** 285, 1898.
213. A Variable Bright Hydrogen Line. No. 21, 1898; also *A.N.*, **145,** 271, 1898.
214. New Variable Stars. No. 24, 1898; also *A.N.*, **146,** 113, 1898.
215. Stars Having Peculiar Spectra. No. 32, 1898; also *A.N.*, **147,** 247, 1898.
216. Objects Having Peculiar Spectra. No. 60, 1901; also *A.N.*, **156,** 293, 1901.
217. Stars Having Peculiar Spectra. No. 76, 1904; also *A.N.*, **165,** 187, 1904.
218. Stars Having Peculiar Spectra. No. 92, 1904; also *A.N.*, **167,** 181, 1905.
219. Stars Having Peculiar Spectra. No. 98, 1905; also *A.N.*, **168,** 303, 1905.
220. A Probable New Star, RS Ophiuchi, No. 99, 1905; also *A.N.*, **169,** 45, 1905.
221. Stars Having Peculiar Spectra: 13 New Variable Stars. No. 111, 1906; also *A.N.*, **171,** 139, 1906.
222. Stars Having Peculiar Spectra: 18 New Variable Stars. No. 124, 1907; also *A.N.*, **174,** 101, 1907.
223. Stars Having Peculiar Spectra: 15 New Variable Stars. No. 132, 1907; also *A.N.*, **176,** 257, 1907.
224. Stars Having Peculiar Spectra: 28 New Variable Stars. No. 143, 1908; also *A.N.*, **179,** 191, 1909.

Ref.
225. Stars Having Peculiar Spectra: 38 New Variable Stars. No. 158, 1910; also *A.N.*, **185,** 255, 1910.
226. Stars Having Peculiar Spectra: 31 New Variable Stars. No. 167, 1911; also *A.N.*, **190,** 107, 1912.
227. The Variable Star, 232848, Z Andromedae. No. 168, 1911; also *A.N.*, **191,** 57, 1912.
228. Stars Having Peculiar Spectra. No. 178, 1913.
229. Stars Having Peculiar Spectra. No. 184, 1914.
230. Stars Having Peculiar Spectra: 13 New Variable Stars. No. 196, 1916.
231. Stars Having Peculiar Spectra: Six New Variable Stars. No. 221, 1920.
232. Stars Having Peculiar Spectra: 16 New Variable Stars. No. 224, 1921.
233. Fifty-one New Variable Stars. No. 225, 1921.
234. CANNON, A. J. Stars Having Peculiar Spectra: Eight New Variable Stars. No. 231, 1922.
235. SHAPLEY, HARLOW, and WILSON, H. H. The Magellanic Clouds, IV: The Absolute Magnitudes of Nebulae, Clusters, and Peculiar Stars in the Large Cloud. No. 271, 1925.
236. SHAPLEY, HARLOW, and WOODS, I. E. Variability of the "Iron Star," XX Ophiuchi. No. 292, 1926.
237. PAYNE, C. H., and HOGG, F. S. A Spectrophotometric Study of the Brighter Pleiades, I: The Line Intensities. No. 303, 1927.
238. HOGG, F. S. A Spectrophotometric Study of the Brighter Pleiades, II: The Continuous Background. No. 309, 1927.
239. GERASIMOVIČ, B. P. Spectrophotometric Temperatures of Early Stars. No. 339, 1929.
240. WILLIAMS, E. T. R. A Spectrophotometric Study of A Stars. No. 348, 1929.
241. PAYNE, C. H., and MAULBETSCH, GEORGETTE. Notes on the Scorpio-Centaurus Cluster, II: The Bright Line Stars and the Problem of Stellar Rotation. No. 364, 1931.
242. Fourth Annual Report of the Photographic Study of Stellar Spectra Conducted at the Harvard College Observatory (reprinted in the *Memorie della Società degli Spettroscopisti Italiani*, **19,** 85, 1890).

Comptes rendus

243. DUFAY, J. Sur la courbe d'énergie de l'étoile P Cygni. **194,** 1454, 1932.
244. DINGLE, HERBERT. *Modern Astrophysics*, p. 284, 1924.

Flagstaff, Lowell Observatory, Bulletins

245. SLIPHER, V. M. A List of Five Stars Having Variable Radial Velocities. **1,** 57, 1904.
246. ———. A New Type of Nebular Spectrum, I: The Spectrum of Hubble's Variable Nebula N.G.C. 2261. **3,** 63, 1918, and Plate.
247. FOOTE, P. D., and MOHLER, F. L. *Origin of Spectra*, p. 96*a*, 1922.

Johannesburg, Union Observatory, Circulars

Ref.

248. WORSSELL, W. M. The Spectrum of μ Centaurus. No. 53, 108, 1921.
249. ———. The Spectrum of η Centaurus. No. 53, 108, 1921.
250. Variable Stars near the Large Magellanic Cloud. No. 61, 240, 1924.
251. JUNG, JOHANNES. *Die Radialgeschwindigkeiten von elf Plejadensternen nach Spektrogrammen von Professor Hartmann.* 1914 (Göttingen inaugural dissertation).

Lyon, l'Observatoire, Publications

252. DUFAY, J. La température de couleur et la courbe d'énergie de l'étoile P Cygni. **1,** 1, 1932; also *Journal des Observateurs,* **15,** 45, 1932.

Mount Hamilton, Lick Observatory, Bulletins

253. CAMPBELL, W. W., and ALBRECHT, SEBASTIAN. Stars Whose Radial Velocities Vary. **5,** 174, 1908–1910.
254. WRIGHT, W. H. Six Southern Stars Having Variable Radial Velocities. **5,** 176, 1908–1910.
255. CAMPBELL, W. W. Note on the Spectrum of 25 Orionis. **6,** 153, 1910–1911.
256. MERRILL, P. W. Preliminary Note on the Spectrum of P Cygni. **6,** 156, 1910–1911.
257. ———. Class B Stars Whose Spectra Contain Bright Hydrogen Lines. **7,** 162, 1912–1913.
258. WATERMAN, E. P. The Visual Region of the Spectrum of Brighter Class A Stars. **8,** 1, 1913–1916.
259. MERRILL, P. W. Stars Whose Spectra Contain Bright Hydrogen Lines: Second Paper. **8,** 23, 1913–1916.
260. ———. The Spectrum of P Cygni between 4340 A and 4650 A. **8,** 24, 1913–1916.
261. MOORE, J. H., and SANFORD, R. F. The Spectrum of η Carinae. **8,** 55, 1913–1916.
262. MOORE, J. H. A Star Having Bright Hydrogen Lines. **8,** 77, 1913–1916.
263. WILSON, R. E. The Orbit of the Spectroscopic Binary υ Sagittarii. **8,** 132, 1913–1916.
264. SANFORD, R. F. Note on η Carinae. **8,** 134, 1913–1916.
265. CAMPBELL, W. W. Note on Lines in the Visual Spectrum of α Cygni. **10,** 108, 1918–1923.
266. WRIGHT, W. H. Further Notes on Lines in the Visual Spectrum of α Cygni. **10,** 108, 1918–1923.
267. MOORE, J. H. Third Catalogue of Spectroscopic Binary Stars. **11,** 141, 1923–1924.
268. YÜ, CH'ING-SUNG. On the Continuous Hydrogen Absorption in Spectra of Class A Stars. **12,** 104, 1924–1927.
269. ———. A Proposed Spectroscopic Method for Determining the Absolute Luminosities of Class A Stars. **12,** 155, 1924–1927.

Ref.

270. ———. A Photometric Study of Stellar Spectra. **15,** 1, 1930–1932.

271. NEUBAUER, F. J. Radial Velocities of 351 Stars Observed at the Chile Station of the Lick Observatory in the Period 1924–1929. **15,** 46, 1930–1932.

272. ———. The Radial Velocity of Nineteen Stars. **15,** 190, 1930–1932.

Mount Hamilton, Lick Observatory, Publications

273. WRIGHT, W. H. Radial Velocities of 150 Stars South of Declination $-20°$. **9,** 73, 1907–1911.

274. CAMPBELL, W. W. Stellar Radial Velocities. **16,** 1928.

275. MOORE, J. H. A General Catalogue of the Radial Velocities of Stars, Nebulae and Clusters. **18,** 1932.

Mount Wilson Observatory, Carnegie Institution of Washington, Contributions

276. ADAMS, W. S. The Three-Prism Stellar Spectrograph of the Mount Wilson Solar Observatory. No. 59; also *Ap. J.*, **35,** 163, 1912.

277. SEARES, F. H., and HUBBLE, E. P. The Color of the Nebulous Stars. No. 187; also *Ap. J.*, **52,** 8, 1920.

278. ADAMS, W. S., and OTHERS. The Parallaxes of 1646 Stars Derived by the Spectroscopic Method. No. 199; also *Ap. J.*, **53,** 13, 1921.

279. HUBBLE, E. P. A General Study of Diffuse Galactic Nebulae. No. 241; also *Ap. J.*, **56,** 162, 1922.

280. MERRILL, P. W., and OTHERS. Discovery and Observations of Stars of Class Be. No. 294; also *Ap. J.*, **61,** 389, 1925.

281. MERRILL, P. W. Two Stellar Spectra of the P Cygni Type. No. 295; also *Ap. J.*, **61,** 418, 1925.

282. JOY, A. H. A Spectrographic Study of Mira Ceti. No. 311; also *Ap. J.*, **63,** 281, 1926.

283. SANFORD, R. F. On the Orbits of Four Spectroscopic Binaries. No. 317; also *Ap. J.*, **64,** 186, 1926.

284. MERRILL, P. W. Stars Whose Spectra Have Bright Iron Lines. No. 334; also *Ap. J.*, **65,** 286, 1927.

285. ———. The Peculiar Bright-Line Spectrum of RY Scuti. No. 349; also *Ap. J.*, **67,** 179, 1928.

286. HUMASON, M. L., and NICHOLSON, S. B. H.D. 163181: A Spectroscopic Binary. No. 353; also *Ap. J.*, **67,** 341, 1928.

287. MERRILL, P. W. Identification of Lines in the Spectrum of η Carinae. No. 354; also *Ap. J.*, **67,** 391, 1928.

288. ———. Bright Iron Lines in the Spectrum of H.D. 45677. No. 355; also *Ap. J.*, **67,** 405, 1928.

289. ———. The Spectrum of B.D.$+11°4673$. No. 381; also *Ap. J.*, **69,** 330, 1929.

Ref.

290. MERRILL, P. W. Notes on the Spectra of Ten Bright-Line Stars of Classes B and A. No. 409; also *Ap. J.*, **72,** 98, 1930.

291. ———. The Spectrum of H.D. 50138. No. 423; also *Ap. J.*, **73,** 348, 1931.

292. ———. A Plane-grating Spectrograph for the Red and Infra-red Regions of Stellar Spectra. No. 432; Plate IX; also *Ap. J.*, **74,** 188, 1931; Plate VIII.

293. ———. Spectrum of the Iron Star XX Ophiuchi. No. 444; also *Ap. J.*, **75,** 133, 1932.

294. ———. The Spectrum of B.D.+11°4673 during the years 1929–1931. No. 450; also *Ap. J.*, **75,** 413, 1932.

295. MERRILL, P. W., and OTHERS. Discovery and Observations of Stars of Class Be: Second Paper. No. 456; also *Ap. J.*, **76,** 156, 1932.

296. MERRILL, P. W. Four Stars Whose Spectra Have Bright Helium Lines. No. 460; also *Ap. J.*, **77,** 44, 1933.

297. ———. Bright Sodium Lines in a Stellar Spectrum. No. 461; also *Ap. J.*, **77,** 51, 1933.

298. MERRILL, P. W., and BURWELL, C. G. Variations in Structure of the Hydrogen Lines in the Spectrum of H.D. 31293. No. 462; also *Ap. J.*, **77,** 103, 1933.

Nature

299. PICKERING, E. C. Draper Memorial Photographs of Stellar Spectra Exhibiting Bright Lines. **34,** 439, 1886.

300. STRUVE, OTTO. The Helium Lines in Stellar Spectra. **122,** 994, 1928.

Observatory

301. LOCKYER, W. J. S. Spectrum of ζ Tauri. **46,** 109, 1923.

302. CORTIE, A. L. γ Cassiopeiae. **47,** 212, 1924.

303. STRATTON, F. J. M. The Spectrum of β Lyrae. **54,** 84, 1931.

Ottawa, Dominion Observatory, Publications

304. HARPER, W. E. ν Geminorum, a Long-Period Binary. **4,** 279, 1920; also *Journal R.A.S. Can.*, **13,** 179, 1919; and *ibid.*, **15,** 148, 1921.

305. ———. Measures of Radial Velocity of κ Cassiopeiae. **4,** 309, 1920.

306. ———. Radial Velocities of Thirty Stars. **4,** 331, 1920.

307. HENROTEAU, F., and HENDERSON, J. P. A Spectrographic Study of Early Class B Stars. **5,** 1, 1922.

308. HENROTEAU, F. A Spectrographic Study of Early Class B Stars: Second Paper. **5,** 47, 1922.

309. ———. A Spectrographic Study of Early Class B Stars: Third Paper. **5,** 331, 1922.

Physical Review

310. STRUVE, OTTO, and SCHWEDE, H. F. Intensities of Balmer Emission Lines in Stellar Spectra. **38,** 1195, 1931. See correction, *Zeitschrift für Astrophysik*, **4,** 179, 1932.

Popular Astronomy

Ref.

311. MAURY, A. C. Note on the Secondary Spectrum and Mass Function of υ Sagittarii. **33,** 700, 1925.

Potsdam, Astrophysikalisches Observatorium, Publicationen

312. VOGEL, H. C., and WILSING, J. Untersuchungen über Spectra von 528 Sternen. **12,** 13, 1899.

Poulkovo, Observatory, Circulars

313. AMBARZUMIAN, V., and KOSIREV, N. On the Spectrum of γ Cassiopeiae. No. 1, 12, 1932.

314. SHAJN, G. Sixteen New and Five Suspected Spectroscopic Binaries. No. 2, 11, 1932.

Preussische Akademie der Wissenschaften, Sitzungsberichte

315. LUDENDORFF, H. Über die Radialgeschwindigkeit von ϵ Aurigae. 1924, p. 66.

Rome, R. Osservatorio Astronomico al Collegio Romano, Contributi astronomici

316. ABETTI, GIORGIO. Esperienze fotografiche con il prisma-obiettivo Merz-Secchi. No. 1, 1920.

Royal Astronomical Society, Monthly Notices

317. Notes from Mr. Huggins' Observatory. **27,** 130, 1867.

318. GILL, SIR DAVID. The Spectrum of η Argus. **61,** [66], 1901.

319. BAXANDALL, F. E. Note on Apparent Changes in the Spectrum of η Carinae. **79,** 619, 1919.

320. LUNT, JOSEPH. On the Spectrum of η Argus. **79,** 621, 1919.

321. PLASKETT, H. H. The Intensity Distribution in the Continuous Spectrum and the Intensities of the Hydrogen Lines in γ Cassiopeiae. **80,** 771, 1920.

322. LOCKYER, W. J. S. The Spectrum of ζ Tauri. **83,** 326, 1923.

323. PLASKETT, J. S. The H and K Lines of Calcium in O-Type Stars. **84,** 80, 1924.

324. LOCKYER, W. J. S. Recent Observations of Some Bright-Hydrogen-Line Stars. **84,** 409, 1924.

325. Stonyhurst College Observatory. The Spectrum of γ Cassiopeiae, $H\beta$ to B. **84,** 576, 1924.

326. LOCKYER, W. J. S. The Spectrum of ϕ Persei (Type Bope). **85,** 580, 1925.

327. ———. The Spectrum of ϕ Persei (Sp. Type Bope) throughout a Complete Cycle (1925–1926). **86,** 474, 1926.

328. ———. The Spectrum of the Bright-Hydrogen-Line Star H.D.C. 20336 in Camelopardalis (Sp. Type B3pe). **86,** 607, 1926.

329. CURTISS, R. H. Absorption Borders in the Spectrum of υ Sagittarii. **88,** 203, 1928.

Ref.

330. CURTISS, R. H. Renewed Visibility of Hydrogen Emission in the Spectrum of f^1 Cygni. **88,** 205, 1928.

331. LOCKYER, W. J. S. Further Observations of Some Bright-Hydrogen-Line Stars, 1924–1927. **88,** 683, 1928.

332. SHAJN, G., and STRUVE, OTTO. On the Rotation of the Stars. **89,** 222, 1929.

333. LOCKYER, W. J. S. Two New Bright-Hydrogen-Line B5-Type Stars. **91,** 187, 1930.

334. ———. The Spectrum of H.D. 20336 in Camelopardalis (Sp. Type B3neη) throughout a Complete Cycle (1925–1930). **91,** 215, 1930.

335. ———. A New Bright-Hydrogen-Line Star of Spectral Type B8 in Lacerta. **91,** 259, 1931.

336. JONES, H. S. Note on the Spectrum of η Carinae. **91,** 794, 1931.

337. PAYNE, C. H. An Interpretation of Absorption and Emission Lines in Early Type Spectra. **92,** 368, 1932.

338. EDWARDS, D. L. Note on Some Peculiarities in Stellar Spectra of Type B. **92,** 389, 1932.

339. PEARCE, J. A. The Coexistence of Stellar and Inter-stellar Calcium Lines in the Massive B9 Star H.D. 698. **92,** 877, 1932.

Royal Astronomical Society of Canada, Journal

340. HENROTEAU, F. The Stars of the β Canis majoris Type. **16,** 58, 1922.

341. FRÉDETTE, J. F. The Riddle of ϕ Persei. **19,** 185, 1925.

Royal Society of London, Philosophical Transactions

342. LOCKYER, SIR J. N. On the Photographic Spectrum of the Great Nebula in Orion. A, **186,** Part I, 83. 1895.

343. MILNE, E. A. Radiative Equilibrium. A, **223,** 236, 1923.

Royal Society of London, Proceedings

344. HUGGINS, SIR WILLIAM, and MILLER, W. A. On the Spectrum of a New Star in Corona Borealis. **15,** 146, 1866; also *M.N.*, **26,** 275, 1866.

345. LE SUEUR, A. On the Nebulae of Argo and Orion and on the Spectrum of Jupiter. **18,** 245, 1869–1870.

346. ———. Observations with the Great Melbourne Telescope in a Letter to Professor Stokes. **19,** 18, 1870–1871.

347. LOCKYER, SIR J. N. On the Chemistry of the Hottest Stars. **61,** 184, 1897, and Plate II.

348. ———. On the Appearance of the Cleveite and Other New Gas Lines in the Hottest Stars. **62,** 53, 1898.

349. MCCLEAN, FRANK. Comparison of Oxygen with the Extra Lines in the Spectra of the Helium Stars. **62,** 422, 1898; Plate VI.

350. LOCKYER, SIR J. N., and BAXANDALL, F. E. Note on the Spectrum of μ Centauri. **74,** 548, 1905.

Science

Ref.

351. MERRILL, P. W. Forbidden Iron Lines in Stellar Spectra. **72,** 407, 1930.

South Kensington, Solar Physics Committee

352. Catalogue of Four Hundred and Seventy of the Brighter Stars Classified According to Their Chemistry at the Solar Physics Observatory, South Kensington. 1902.

Die Sterne

353. STRUVE, OTTO. Eine Hypothese zur Erklärung der Hellen Linien in Sternspektren. **12,** 1, 1932.

Victoria, Dominion Astrophysical Observatory, Publications

354. PLASKETT, J. S. The O-Type Stars. **2,** 302, 1924, and Plate I.

355. HILL, S. N. The Orbits of Two Spectroscopic Binaries. **3,** 349, 1927; abstract in *Pop. Astr.*, **34,** 557, 1926.

356. PLASKETT, J. S. Three Peculiar Spectra. **4,** 1, 1931; also *M.N.*, **87,** 31, 1927.

357. ———. *Ibid.*, Plate I.

358. ———. Notes on υ Sagittarii. **4,** 111, 1931.

359. PLASKETT, H. H. The Composite Stellar and Nebular Spectrum of Z Andromedae. **4,** 119, 1931.

360. BEALS, C. S. The Wolf-Rayet Stars. **4,** 271, 1931; also *M.N.*, **90,** 202, 1930.

361. PLASKETT, J. S., and PEARCE, J. A. The Radial Velocities of 523 O and B type Stars Obtained at Victoria, 1923–1929. **5,** 1, 1931.

362. ———. A Catalogue of the Radial Velocities of O and B Type Stars. **5,** 99, 1931.

Zeitschrift für Astrophysik

363. STRASSL, HANS. Die Intensitätsverteilung in den Spektren der helleren Plejadensterne. **5,** 205, 1932; also *Veröffentlichungen der Universität-Sternwarte Göttingen*, No. 29.

DISCUSSION

Discovery.—Table IV shows the distribution of the discoveries of Be stars, beginning with γ Cassiopeiae and β Lyrae by Secchi in 1866. Only 5 of the 410 stars in Table I were discovered visually. The photographic surveys with the objective prism inaugurated at the Harvard Observatory by E. C. Pickering in 1886 produced rich results in this as in other fields of stellar spectroscopy. The lines used for the detection of hydrogen emission were $H\beta$ and $H\gamma$. At Mount Wilson, on the other hand, it has been possible to take advantage of the much stronger $H\alpha$ line, because of the development of rapid panchromatic emulsions not available to the early observers.

Distribution in type and magnitude.—The distribution of the types and apparent magnitudes of the 410 stars is shown in Table V. The 13 variable stars, which are tabulated according to their median magnitudes, are included in the body of the table but are also given separately in the last line and the last column of the table. Five are of the R Coronae type, while 1, β Lyrae, is an eclipsing variable. The others are said to be irregular or like novae.

TABLE IV

DISCOVERY OF 410 Be STARS

	Visual	Photographic	
		Objective Prism	Slit Spectrograph
Secchi	γ Cassiop.	.....	.....
	β Lyrae	.....	.....
Le Sueur	η Carinae	.....	.....
Campbell	Alcyone	.....	.....
Espin	H.R. 985	.....	.....
Harvard	.....	124	.....
Mount Wilson	.....	207*	30
Lockyer	.....	2	.....
Lick (including Chile)	.....	.....	15
Victoria	.....	.....	14
Yerkes	.....	.....	5
Lowell	.....	.....	3
University of Michigan	.....	.....	2
Simeis	.....	.....	2
Allegheny	.....	.....	1
Total	5	333	72

* All the Mount Wilson stars credited to the objective prism were confirmed on slit spectrograms. Without such confirmation a number of them could not have been announced as certainly having bright lines.

The data show the normal increase in the numbers of stars with magnitude down to the fifth magnitude, and a much slower progression thereafter, the maximum number being in the eighth magnitude. These numbers reflect chiefly the thoroughness with which stars of different magnitudes have been observed. In this connection Table I*a* in *Mount Wilson Contribution* No. 456[10] is instructive. It appears that for the detection of bright lines in B-type stars the Harvard surveys were most nearly complete among stars brighter

[10] *Astrophysical Journal*, **76**, 156, 1932.

than magnitude 5.0, and that the Mount Wilson surveys were most effective for magnitudes 7 and 8. The relatively large number of peculiar (Pec.) and P Cygni (Beq) spectra among the fainter magnitudes arises from the great intensity of the hydrogen emission in these stars and the consequent ease of detection.

A more detailed distribution among the various spectral subdivisions is shown in Table VI, which also indicates the numbers hav-

TABLE V

DISTRIBUTION OF 410 Be STARS IN TYPE AND MAGNITUDE

Type	Magnitude															
	1*	2	3	4	5	6	7	8	9	10	11	12	13	?	Total	Variables
O6–O9	....	....	....	1	1	....	2	1	....	....	....	....	....	....	5	0
B0	....	1	....	2	1	4	6	10	10	2	....	....	....	....	36	1
B1	....	....	....	4	1	6	5	7	1	....	....	....	....	....	24	0
B2	....	....	1	1	4	8	15	16	7	2	....	....	....	....	54	0
B3	....	2	4	16	18	16	20	14	12	2	....	....	....	....	104	0
B4–B6	....	....	4	14	4	11	7	12	5	1	....	....	....	....	58	0
B8	....	1	1	1	9	3	4	8	....	....	....	....	....	....	27	0
B9	....	....	....	1	2	3	1	1	1	....	....	....	....	....	9	1
B	....	....	1	....	....	....	6	6	17	8	7	1	1	....	47	3
A	1	....	....	2	....	3	4	3	....	....	....	....	....	....	13	1
Pec	....	....	....	....	....	....	1	1	3	1	2	2	1	2	13	6
Beq†	....	....	....	....	....	1	1	1	6	1	4	4	1	1	20	1
Total	1	4	11	42	40	55	72	80	62	17	13	7	3	3	410	.....
Variables	0	0	1	0	0	1	3	2	2	2	0	1	1	0	.....	13

* The magnitude intervals are 1.00–1.99, 2.00–2.99, etc.

† Four additional *q* stars are included in their assigned spectral subdivisions.

ing nebulous (n) and sharp (s) lines. The lower intensity of the hydrogen emission and the greater stellar luminosity are characteristics of the "s" stars[11] which should be kept in mind in general investigations of Be stars.

Very few bright-line stars of the kind under consideration are found in class O. The maximum frequency occurs at B3; the numbers then rapidly decline toward class A.

Twenty-eight stars of the P Cygni type are listed in Table VII. The first nine are in the Greater Magellanic Cloud. The last four have variable spectra which show P Cygni characteristics only at times. The high galactic latitudes of these stars suggest that their nature is not the same as that of the preceding stars. The approxi-

[11] *Publications of the Astronomical Society of the Pacific*, **45**, 49, 1933.

mate absolute magnitude of the companion to *o* Ceti is +7; that of the companion to R Aquarii, +2.

To examine the ratio of the total number of stars in the various spectral subdivisions to the number having bright lines, we may use the counts of stars in the *Henry Draper Catalogue* made by Charlier[12] and by Shapley and Miss Cannon.[13] Counting in Table I only those stars which are in the *Henry Draper Catalogue*, we have

TABLE VI

DETAILED DISTRIBUTION IN SPECTRAL TYPE OF 410 Be STARS

Class	n	s	Unclassified	Total
O6	0	0	1	1
O7	1	0	0	1
O8	0	0	2	2
O9	0	1	0	1
Bo	24	5	7	36
B1	9	8	7	24
B2	24	4	26	54
B3	58	3	43	104
B4	5	0	2	7
B5	32	1	15	48
B6	2	0	1	3
B8	17	2	8	27
B9	3	1	5	9
B	6	0	61	67
Ao	1	2	3	6
A2–A4	0	2	2	4
A	0	0	3	3
Pec	0	0	13	13
Totals	182	29	199	410

the data in Table VIII.[14] The ratio for B1 is unduly small because this subdivision is relatively little used in the *Henry Draper Catalogue* except for stars brighter than the fifth magnitude, whereas observers with slit spectrographs apparently have used B1 as freely as Bo. Of the 24 H.D. stars classified as B1 in Table I, only 7 are thus classified in the *Henry Draper Catalogue*.[15] For this number, the ratio for all stars becomes 10.9, or 10.7 for those brighter than mag-

[12] *Meddelande från Lunds Astronomiska Observatorium*, No. 19, Table 3*c*, p. 14, 1926.

[13] *Harvard Circular*, No. 226, 1921.

[14] In Tables VIII–XI, B5 includes also the small number of B4 and B6 stars.

[15] Their average magnitude is 5.7, compared with 7.5 for the remaining 17 stars.

nitude 9.0. These values are probably more appropriate than the smaller ratios given in Table VIII. It thus appears that stars of class B2 have a more general tendency toward emission than those

TABLE VII

P CYGNI TYPE STARS

MWC	H.D.	Desig.	R.A. 1900	Dec. 1900	l	b	Mag.	Type
102	33540*	.....	$5^h\ 5^m8$	−71° 3′	249°	−34°	*12.3*	Beq
105	34664	In N.G.C. 1871	5 14.0	−67 34	245	−34	*11.4*	Beq
106	.....	Anon	5 14.4	−69 28	247	−34	*11.4*	Beq
108	35343	S Dor	5 18.9	−69 21	246	−33	9 v	Beq
		Anon	5 28.5	−69 4	246	−32	*13.0*	Beq
113	.....	(383)	5 29.0	−69 13	246	−32	*12.2*	Beq
121	37836	401	5 36.2	−69 44	247	−32	*10.5*	Beq
123	37974	420	5 37.2	−69 26	246	−32	*11.3*	Beq
126	38489	478	5 41.0	−69 26	246	−31	*12.0*	Beq
145	45910	1267	6 25.2	+ 5 57	173	0	6.7	Beq
161	51480	1774	6 52.4	−10 41	191	− 2	7.0	B8eq
162	51585	.....	6 52.8	+16 28	167	+10	.....	Beq?
165	53179	Z CMa	6 59.0	−11 24	192	− 1	9.1	Beq
215	94878	2855	10 52.0	−59 52	257	− 1	8.5	Beq
216	94910	2860	10 52.2	−59 55	257	− 1	7.6	Beq
236	138403	1889	15 26.7	−71 34	283	−14	*9.0*	Beq
238	141969	3171	15 46.7	−65 52	288	−10	*9.2*	Beq
242	151895	.....	16 45.1	−64 4	293	−14	*12.5*	Beq
243	152236	ζ^1 Sco	16 47.0	−42 12	311	0	4.9	B1seq
267	161044	11816	17 38.2	−46 3	313	−10	11.0	Beq
272	.....	11944	17 41.9	−27 59	329	− 1	9.0	Beq
293	169226	5034	18 18.6	−12 15	347	− 1	9.1	Be(q)
338	193237	P Cyg	20 14.1	+37 43	43	0	4.9	B1eq
374	.....	3487	21 32.2	+47 28	60	− 4	9.1	B3eq

Stars at Times Resembling P Cygni

35	.....	Comp. *o* Cet	2^h14^m3	− 3° 26′	137°	−57°	10 v	Bep
269	161114	XX Oph	17 38.6	− 6 14	347	+10	10 v	Pec.
379	207757	*4673*	21 46.2	+12 9	38	−32	7.6v	Bep
400	.....	Comp. R Aqr	23 38.6	−15 50	37	−71	9 v	Pec.

* In *Harvard Bulletin* No. 891, received after the completion of the present manuscript, there is the following note: "H.D. 33540, hitherto assumed to be of the P Cygni class. On recent photographs, however, the nebular lines are clearly seen. *Hβ* is twice as strong as the chief nebular line. On plates taken with the 10-inch telescope, the continuous spectrum is strong and several absorption lines are visible."

This *Bulletin* also lists two additional stars of the P Cygni type, as tabulated. These stars should be included in Table I, and possibly H.D. 33540 should be removed.

Desig.	R.A. (1900)	Dec. (1900)	Mag.
C.P.D.−69°427	$5^h14^m39^s$	−69°38′.2	11.6
	5 37 32	−69 33.1	11.1

of either earlier or later spectral subdivisions. The relative number of bright-line stars decreases very rapidly from B_3 to Ao.

TABLE VIII

STARS IN THE *Henry Draper Catalogue*

TYPE	ALL STARS			STARS BRIGHTER THAN MAG. 9.0*		
	H.D.	Em.	Ratio	H.D.	Em.	Ratio
Bo	376	26	14.5	289	21	13.8
B1	76	24	(3.2)†	75	23	(3.3)‡
B2	369	44	8.4	305	41	7.4
B3	1041	90	11.6	902	89	10.1
Bo–B3	1862	184	10.1	1571	174	9.0
B5	1348	50	27.0	1021	49	20.8
B8	4395	25	176	2318	24	96.6
B9	8408	8	1051	4096	7	585
Ao	30816	6	5136	11184	5	2237
A2, 3(4)	20630	4	5157	8734	4	2184

* For the last four lines the limiting magnitude is 8.75 instead of 8.99.

† 10.9 is considered a more representative value.

‡ 10.7 is considered a more representative value.

TABLE IX

DISTRIBUTION OF H.D. STARS IN TYPE AND MAGNITUDE
Bo–B5

TYPE	MAGNITUDE							
	Br.–4.9		5.0–6.9		7.0–8.9		9.0–Ft.	
	H.D.	Em.	H.D.	Em.	H.D.	Em.	H.D.	Em.
Bo	19	3	69	5	201	13	87	5
B1	30	4	26	7	19	12	1	1
B2	35	2	68	12	202	27	64	3
B3	116	22	387	34	399	33	139	1
Bo–B3	200	31	550	58	821	85	291	10
B5	72	18	288	15	661	16	327	1

The distribution of the H.D. stars among the spectral subdivisions and several intervals of apparent magnitude is shown in Tables IX and X. The ratios, all stars to those having bright lines, computed from Tables IX and X, are in Table XI, which brings out several

facts of interest. The rapid increase of the ratios from B3 to Ao, already remarked upon, corresponds to the physical behavior of stars with decreasing surface temperature, whereas, in any given type,

TABLE X

DISTRIBUTION OF H.D. STARS IN TYPE AND MAGNITUDE
B8–A3

TYPE	MAGNITUDE							
	Br.–6.25		6.26–7.75		7.76–8.75		8.76–Ft.	
	H.D.	Em.	H.D.	Em.	H.D.	Em.	H.D.	Em.
B8	274	13	772	6	1272	5	2077	1
B9	280	3	1448	4	2368	0	4312	1
Ao	736	0	2824	2	7624	3	19632	1
A2, 3, (4)	728	1	2264	3	5742	0	11896	0

TABLE XI

DISTRIBUTION OF RATIOS, ALL/EMISSION, IN TYPE AND MAGNITUDE

TYPE / MAG.	CHARLIER		*Harvard Circular*, No. 226			
	Bo–B3	B5	B8	B9	Ao	A2, 3, (4)
Br.–4.9	6.4	4.0	.....	.....	.....	.....
Br.–6.25	.....	.....	21.1	93.3	>736	728
5.00–6.99	9.5	19.2	.....	.....	.....	.....
6.26–7.75	.....	.....	129	362	1412	755
7.00–8.99	9.7	41.3	.....	.....	.....	.....
7.76–8.75	.....	.....	254	>2368	2541	>5742
8.76–Ft.	.....	.....	2077	4312	19632	>11896
9.00–Ft.	29.1	327	.....	.....	.....	.....
All	10.1	27.0	176	1051	5136	5157

the increase of ratio with apparent magnitude indicates a declining discovery factor. For classes Bo–B3 this factor changes slowly until magnitude 9.0 is reached, below which, of course, surveys for bright lines are as yet wholly inadequate.[16] For classes B5–Ao the ratios

[16] Among such faint stars the plates of the Mount Wilson *Hα* survey are, for the most part, competent to disclose only those objects with unusually intense bright lines.

increase with magnitude much more rapidly than for classes B0–B3, probably because of the low intensity of the hydrogen emission in the later classes and the consequent difficulty of detection in objective-prism spectra of low dispersion. In the more thorough examination given the spectra of the brighter stars, the relative disadvantage of the emission-line stars of classes B5–A0 is less marked.

The *Hα* survey has not included the southern sky, and many bright-line stars in the northern sky have undoubtedly as yet been missed. In view of these facts it seems probable that among the early B stars, at least those in class B2, one star in every five or six actually has bright lines. The data suggest that a relatively large number of bright-line stars remain to be discovered in classes B5–A0. For the detection of bright lines in these classes observations with slit spectrographs will be especially effective.

Galactic distribution.—To a first approximation the galactic distribution of B-type stars whose spectra have emission lines resembles that of other B stars, although the emission stars have, perhaps, a somewhat stronger tendency to appear in condensed groups (Fig. 2*a*). A comparison of the distribution of the brighter emission stars of types B0–B5 with that of non-emission stars of the same types shows, however, a certain general difference. Such a comparison is conveniently made by using the data and charts in *Harvard Circular* No. 239 by Harlow Shapley and Annie J. Cannon. The normal stars exhibit a systematic departure from the galactic circle, attributed to a "local system" or flattened condensation of stars in the neighborhood of the sun, whose plane is inclined some 15° to that of the galaxy. The angular departure is greatest for the brightest stars and disappears in the magnitude interval 7.26–8.25 (Fig. 3). Be stars brighter than magnitude 5.26 and those in the interval 5.26–6.25 show the effects of the local system, although less strongly than do the corresponding non-emission stars; but for Be stars of magnitudes 6.26–7.25, as well as those of magnitudes 7.26–8.25, the average galactic latitudes are small and not suggestive of the local system. It appears, therefore, that the divergence from the galactic plane characteristic of the local system is less strongly marked for emission than for non-emission stars of the same apparent magnitudes, and disappears at a brighter magnitude. This is probably

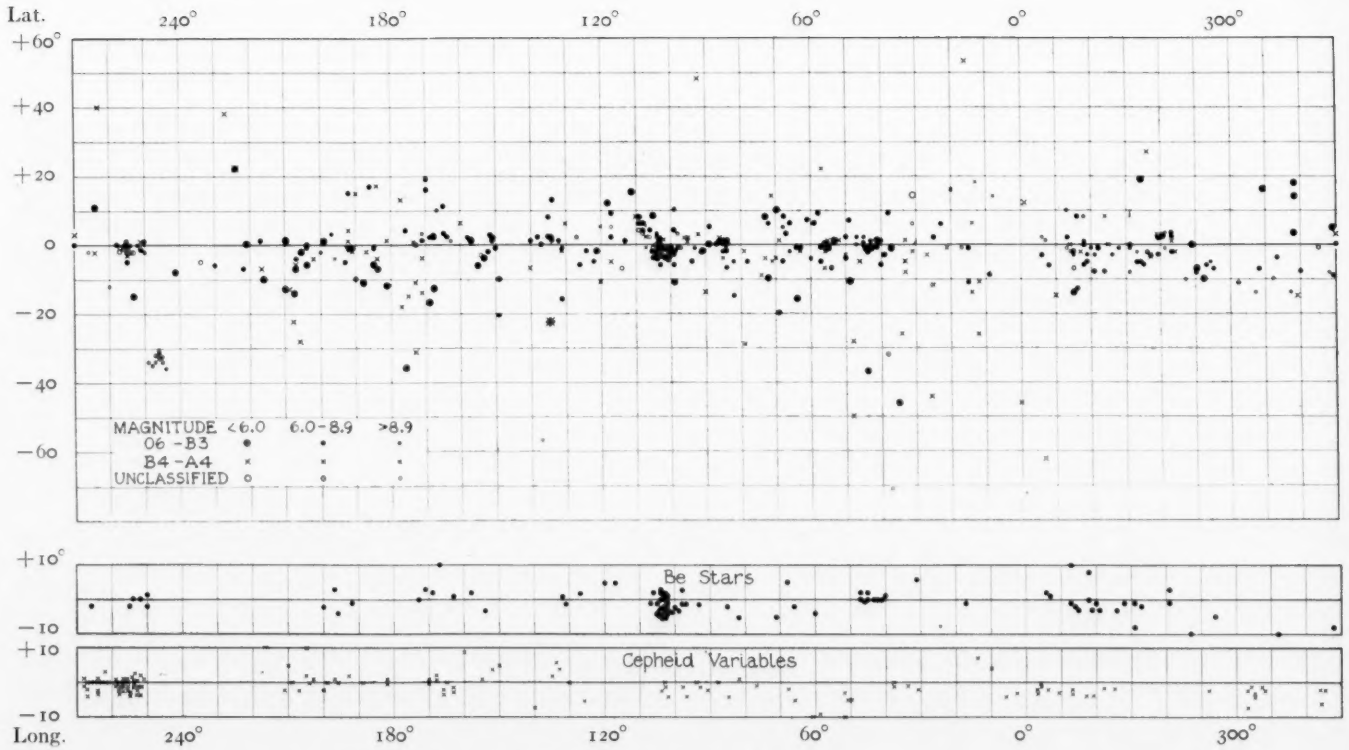


FIG. 2*a* (above).—Galactic distribution of Be stars

FIG. 2*b* (below).—Galactic distribution of faint Be stars and faint Cepheid variables

because the emission stars are intrinsically brighter than the others, and consequently the boundary of the local system is reached at a somewhat brighter apparent magnitude. The difference in luminosity may be about 1 mag.

The numbers of stars in various galactic zones are shown in Table XII. Seventy-seven per cent are within 10° of the galactic circle.

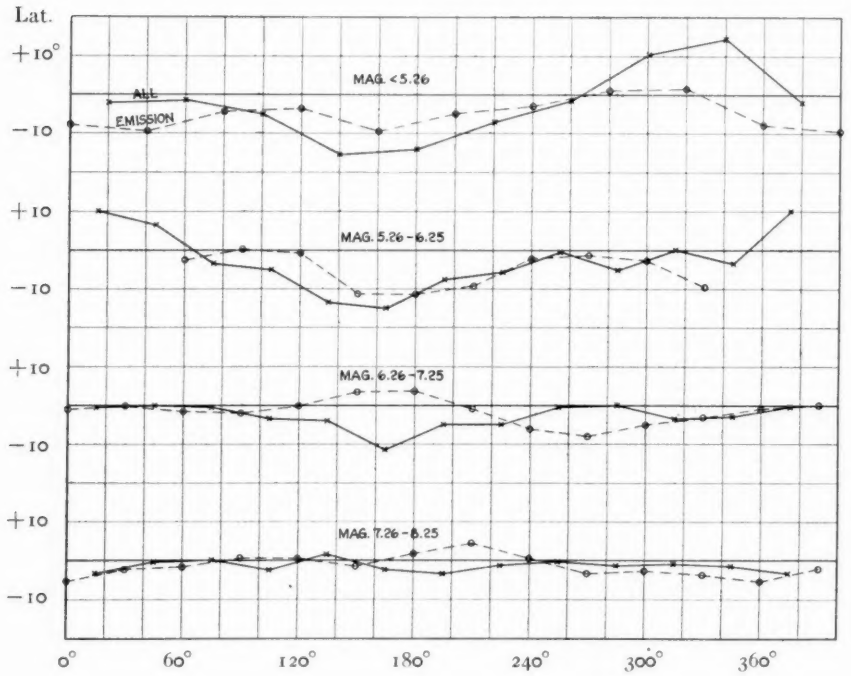


FIG. 3.—Mean galactic latitudes and longitudes of stars of types Bo–B5

The galactic positions of the stars in Table I are plotted in Figure 2*a*. The irregularities in distribution are striking; the Be stars exhibit to a high degree that property to which Miss Clerke applied the adjective "gregarious." Table XIII lists 12 areas in which Be stars are particularly numerous. Some of them, e.g., Nos. 1, 7, 8, probably represent clusters relatively near us, while others, notably Nos. 2 and 10, are apparently portions of the Milky Way clouds which chance to suffer relatively little dimming by absorbing ma-

terial. Wolf-Rayet stars are numerous in areas 2 and 10, while few are found in groups of the other type.

Group 10 is marked by a well-defined boundary at longitude 250°. An abrupt rise in the general stellar density is shown at this point

TABLE XII

NUMBERS OF STARS AT VARIOUS GALACTIC LATITUDES

Gal. Lat.	North	South
90°–30°	4	22*
30 –20	3	10
20 –10	22	32
10 – 0	127	190
90 – 0	156	254

* Including 11 stars in the Greater Magellanic Cloud.

TABLE XIII

AREAS RICH IN Be STARS

No.	G. Long.	G. Lat.	R.A.	Dec.	Remarks
1	40°	−40°	22^h14^m	+ 7°	Scattered group of bright stars
2	44	0	20 16	+38	Near γ and P Cygni
3	54	0	20 52	+46	Small group of bright stars
4	85	0	0 0	+62	Cassiopeia
5	103	− 3	2 16	+57	Region of double cluster in Perseus
6	107	+ 3	3 2	+60	
7	135	−22	3 44	+24	Pleiades
8	206	− 5	7 10	−25	Group of bright stars
9	247	−33	5 22	−70	Greater Magellanic Cloud
10	254	− 1	10 30	−59	Near η Carinae
11	320	− 1	17 16	−35	Scorpius
12	342	− 2	18 12	−17	Sagittarius

by sixteenth-magnitude stars but not by those down to magnitude 13.5.[17] This presumably indicates that the Be stars in this region are much brighter intrinsically than the average background stars. The region of the double cluster in Perseus, area 5, is extraordinarily

[17] F. H. Seares and M. C. Joyner, *Mt. Wilson Contr.*, No. 346; *Astrophysical Journal*, **67**, 24, 1928.

rich in Be stars, although the general stellar density is scarcely equal to the average for the galaxy. The characteristic spectroscopic properties of the stars in this region invite detailed investigation.

The following areas along the Milky Way are deficient in Be stars: longitudes 355°–15°, 140°–150°, 220°–250°, 285°–310°. In these regions dark clouds may hide the more distant stars.

The distribution of faint Cepheid variables is remarkably similar to that of faint Be stars (Fig. 2*b*). This is probably because these intrinsically bright objects are so distant that their apparent distribution is largely governed by the location of dark absorbing clouds.

CARNEGIE INSTITUTION OF WASHINGTON
MOUNT WILSON OBSERVATORY
March 1933

SYSTEMATIC CORRECTIONS TO MAGNITUDES AND AN EXTENSION OF THE POLAR SEQUENCE[1]

By FREDERICK H. SEARES

ABSTRACT

It is shown that the statistical error involved in comparisons of magnitudes has not appreciably affected the systematic corrections to various catalogues printed in an Appendix to the *Report of the Commission on Stellar Photometry* (*Transactions of the International Astronomical Union*, **4**, 140, 1932).

These corrections have been slightly revised and utilized to form mean *Pg* and *Pv* magnitudes on the international scale for about 375 polar stars brighter than the tenth magnitude. The mean *Pv* magnitudes have been tested and strengthened by means of special observations supplied by Dr. F. E. Ross. The internal agreement of the data from various sources, both in scale and in color (Tables III and IV), shows that the corrections applied to the catalogues are substantially free from error and that the mean magnitudes are in close accordance with the international system (Table II).

The Greenwich effective wave-lengths have been calibrated in terms of color index (Table V).

The appearance of the fourth volume of the *Transactions of the International Astronomical Union* brings to my attention for the first time a communication by Professor Knut Lundmark which is printed as an Appendix (p. 153) to the *Report of the Commission on Stellar Photometry*.

Lundmark questions the validity of the systematic corrections to certain catalogues of magnitude derived by me (*op. cit.*, pp. 140–151) on the ground that the differences between the systems of the different catalogues used in determining the corrections may be affected by statistical error of the type discussed by A. Pannekoek[2] and later by S. Holm.[3] I was fully aware of the work of both Pannekoek and Holm and, in fact, during the year preceding the appearance of Pannekoek's memoir, in connection with another question, I had had occasion to discuss this same type of error.[4] The effect of such error was carefully considered before deriving the corrections in question. It appeared that in most cases the corrections would be very small

[1] *Contributions from the Mount Wilson Observatory, Carnegie Institution of Washington*, No. 472.

[2] *Publications of the Astronomical Institute of the University of Amsterdam*, No. 1, p. 19, 1924.

[3] *Meddelanden från Lunds Astronomiska Observatorium*, Ser. 2, No. 59, 1931.

[4] *Monthly Notices of the Royal Astronomical Society*, **84**, 15, 1923.

and that in any event they could not be determined with an accuracy which would justify their inclusion, because of lack of knowledge of the mean errors of the various catalogues.

Although lack of space necessitated the omission of many details from the *Report*, the answer to Lundmark's question was given, implicitly at least, in a letter sent for presentation to the Commission at the time of the meeting in Cambridge. Since neither the communication by Lundmark nor the minutes of the meeting of the Commission (*ibid.*, p. 247) includes any reference to the supporting evidence given in this letter, it is desirable that the letter now be printed.[5] The relevant part is as follows:

I had hoped to be able to submit additional polar standards for the consideration of the Commission at this meeting, but it has not been possible to finish the necessary calculations. Although not intended for inclusion in the *Report*, the following details may be of general interest to the Commission.

The extension of the NPS standards was begun with the stars in the *Pg* lists of Miss Payne and De Sitter (HP, L), approximately 160 in all after excluding doubles. Most of these stars also occur in GAP, Y, Gr and S. Reduced to the IPg system by Table IV of the *Report*, with the aid of HD spectra for color corrections, the magnitudes of the individual catalogues show an average deviation of 0.052 mag. from the means.

Mean *Pv* magnitudes were then obtained from PD, YPv and PDP with the aid of *Report*, equation (4) and Table VIII, the average deviation for this first approximation being 0.057 mag. Color indices found from the mean *Pg* and *Pv* magnitudes were then used for a provisional calibration of the Greenwich effec-

[5] The following notation is used for *Pg* magnitudes:

Gr, Greenwich Photographic Magnitudes $+75°$ to $+90°$, 1913
S, Simeis Photographic Magnitudes, *Bulletin, Poulkovo*, No. 72, 1915
HP, Harvard, Miss Payne, HB, No. 881, 1931
L, Leiden, De Sitter, *Bulletin of the Astronomical Institutes of the Netherlands*, No. 210, 1930
GAP, *Göttingen Aktinometrie*, B, p. 42, 1912; polar stars
YPg, Parkhurst, *Yerkes Actinometry*, 1912

For visual and *Pv* magnitudes:

YPv, *Yerkes Actinometry*, 1912
PD, Potsdam General Catalogue, *Publikationen*, **17**, 1907
PDP, Potsdam Polar Catalogue, *ibid.*, **26**, Part II, 1927

Further, NPS = North Polar Sequence; IPg and IPv indicate magnitudes on the international scale, usually those of the NPS stars themselves. $\overline{Pg}$ and $\overline{Pv}$ refer to the system of mean magnitudes now in process of derivation which will eventually serve as an extension of the NPS. Although on the international system, the international designation is not yet used as the results are still provisional.

tive wave-lengths, which, in turn, were combined with the well-established *Pg* scale to test the *Pv* scale. This comparison led to a revision of the YPv corrections in Table VIII for magnitudes 7.25 and 7.75.

It was found at an early stage in the investigation that about 75 stars having *Pg* magnitudes in two to four catalogues (GAP, YPg, Gr, S) and *Pv* values in at

PHOTOGRAPHIC

$\overline{Pg}$	$\overline{Pg}-Catalogue$						C_m-C_λ
	Gr	S	HP	L	GAP	YPg	
4.4	+8 2			+1 2	−1 2	− 8 2	−8 2
5.5	−3 17	+1 16	+2 14	0 15	0 13	+ 1 17	−4 15
6.25	−1 18	+2 18	−2 17	0 18	+1 18	0 18	0 18
6.62	−1 18	−3 18	+3 17	0 17	+2 15	0 17	+2 16
6.88	+2 18	−1 18	+1 17	+1 17	−3 15	0 18	−2 17
7.12	+3 19	+1 19	+1 16	+1 18	−4 17	− 2 18	+2 19
7.38	+2 30	−1 30	0 29	0 30	+1 25	− 1 28	0 26
7.62	+2 37	−3 36	−2 34	+1 34	0 22	+ 1 28	+3 34
7.88	+7 23	−2 23	−6 11	+1 11	−2 13	− 1 18	−1 18
8.12	+2 22	−3 22			+7 11	− 3 21	0 20
8.38	−1 18	+1 18				0 12	0 15
8.62	0 19	−2 19				+ 3 13	−1 18
8.88	0 17	+1 17				− 4 4	+3 15
9.24	−1 26	0 26				+14 1	−1 25
9.75	+1 27	0 27					−2 50
10.15	0 7	−1 7					+1 38
Total no. stars	318	314	155	162	151	215	346

PHOTOVISUAL

$\overline{Pv}$	$\overline{Pv}-Pv_\lambda$	$\overline{Pv}-Catalogue$		
		YPv	PD	PDP
4.6	+1 9	−6 9	+6 9	
5.25	−7 12	−3 14	+3 14	
5.75	+1 14	+2 14	−1 14	−11 1
6.25	−2 31	+3 32	−2 32	− 5 7
6.75	−1 40	+4 43	0 43	− 5 26
7.12	−1 35	+1 38	+1 38	− 2 33
7.38	+1 30	+3 31	−1 31	− 2 30
7.75	+1 21	0 34	−4 32	+ 3 32
8.36	−3 25			
8.90	+2 24			
9.41	+3 46			
9.66	−1 43			
Total no. stars	330	215	213	129

least two (YPv, PD, PDP) could be added to the list of standards. The limit for these stars is about 9.0 *Pg*. Later about 140 more stars, mostly between *Pg*=8.0 and 10.2, were also included, thus giving in all a list of 373 stars. The accidental errors of the mean magnitudes of faint stars will of course be larger than those of the brighter objects, but the scale and color system should be dependable. The reduction to the international system has been greatly facilitated by the Greenwich effective wave-lengths, which seem to be internally consistent and of excellent precision.

After color indices had been determined, the color corrections were recomputed and both *Pg* and *Pv* data were again combined. The original color coefficients seem to be adequate, for the residuals from the second approximation for the magnitudes indicate homogeneity in color.

The present status in respect to scale divergence is shown by the accompanying tables, in which each column gives a difference expressed in 0.01 mag. as unit, followed by the number of stars on which the result depends. No important systematic effects remain in the *Pg* data. The *Pv* results are less satisfactory and small adjustments must still be made in the scale corrections for YPv and PDP. It is noteworthy, however, that the mean *Pv* scale is consistent with the *Pg* scale. For example, color indices derived from Greenwich effective wavelengths when applied to *Pg* magnitudes give photovisual values which are independent of those from the *Pv* catalogues. The accordant mean differences $Pv-Pv_\lambda$ are in the second column of the *Pv* table.

The last column of the *Pg* table (C_m-C_λ) shows the systematic accordance of the two systems of color indices. The average difference without regard to sign for 276 stars, chiefly accidental error, is ± 0.087 mag.

These various results are still provisional, but sufficient to indicate a successful outcome for the undertaking, which will be completed as soon as possible.

The statistical error in question arises from the fact that the accidental errors in any observed characteristic x generally produce a systematic error in the mean of a series of values of x which have been grouped according to x and fall within the finite interval x to $x+\Delta x$. If X represent the true value of x, the correction which eliminates the systematic error from the mean is[6]

$$c=\overline{X}-\overline{x}=\epsilon^2\frac{F'(x)}{F(x)},$$

where ϵ is the mean error of x and the fraction represents the logarithmic derivative of the frequency function of x. In comparing the magnitudes of two catalogues, m_1 and m_2, we calculate mean differences for small intervals of m in one or the other of the catalogues. For a grouping of differences according to m_2, we obtain

$$\Delta m_2=\overline{m_1-m_2}=\overline{m}_1-\overline{m}_2,$$

which is affected by the systematic error in $\overline{m}_2$. No error of this kind arises from $\overline{m}_1$, because the grouping is according to m_2 and there has been no preferential selection of the accidental errors affecting m_1.

[6] Seares, *loc. cit.*

The correction required by Δm_2 is therefore $-c_2$. For a grouping of these same differences, $m_1 - m_2$, according to m_1, we obtain the mean Δm_1, which requires the correction $+c_1$. The corrections involve the mean errors of the two catalogues ϵ_1 and ϵ_2, respectively, and practically the same value of the logarithmic derivative because substantially the same stars are used for both groupings.

From these details it follows that in general it is advantageous to group the differences according to intervals of magnitude for the more precise of the two catalogues, and, further, that if the precision is the same for the two, the formation of the mean of Δm_1 and Δm_2 eliminates the systematic statistical error and gives the true difference between the two magnitude systems.

With these preliminaries stated, the implications of the foregoing letter are obvious. First, the mean deviations indicate an average mean error for a single magnitude in any catalogue of approximately ± 0.07 mag. In order that the statistical error may amount to as much as 0.01 mag., the logarithmic derivative must therefore attain a value of about 2. The run in the numbers of stars shown in the tables, with allowance for inequality in some of the intervals, shows that any such value can be attained only at the beginning and end of the frequency-curve where the numbers of stars are so small that the inclusion or rejection of two or three stars radically alters the result and makes the calculated corrections of very doubtful validity. It is of course true that just at these points the mean errors themselves will generally be larger than the average; but this circumstance only widens the interval of uncertainty within which the true correction lies. In general, therefore, the comparisons of magnitude scales for individual catalogues cannot have been appreciably affected by statistical error. Further, any residual effect must have been at least partially compensated by the network adjustment which was used; and, finally, the differences shown in the tables themselves cannot have been affected by the final intercomparison because in this case the grouping was according to mean magnitudes, which naturally are much more precise than those of the individual catalogues.[7]

The results accompanying the *Report* were admittedly provisional,

[7] In the May issue of the *Astrophysical Journal* (**77**, 229, 1933), which has just come to hand, Holm has calculated the statistical errors affecting, first, a comparison of

but statistical errors certainly were not a source of any great uncertainty. Nor was there any large inhomogeneity in the system of $\overline{Pg}$ and $\overline{Pv}$ magnitudes defined by the systematic corrections to the various catalogues. The values of $\overline{Pv}-Pv_\lambda$ establish this fact definitely. The important question was rather the status of this system as a whole relative to the international system of the NPS. As far as it went, the evidence indicated that the agreement was all that could be expected from comparisons which at the best involved only sixteen standard polar stars—say a combined scale and zero-point error of 0.02 or 0.03 mag. and a rather large uncertainty in color because of the very small number of available red standard stars.

Yerkes magnitudes, Y (Parkhurst) with Y_2 (Fairley); and second, of Y with Greenwich (GrPg).

Y and Y_2.—The statistical corrections found are based on the assumption that the external mean errors of the two catalogues are both equal to $\pm$0.099 mag. I doubt if this assumption can be justified. The average deviation for 162 values of Y from the mean *Pg* system described in the text of the present article is only slightly in excess of $\pm$0.05 mag., a result which indicates for the external mean error of Y a value of about $\pm$0.07. Most of the discordance between Y and Y_2 (average difference $=\pm$0.140 mag.) seems therefore to arise from Y_2 and probably has its origin in the systematic error in R.A. Since Holm has grouped the differences according to Y, the mean error to be used in calculating the corrections is that of this catalogue. His corrections, the largest of which is +0.018, would therefore seem to be about twice the true values.

Of Eberhard's comparison of Y and Y_2, Holm states (*ibid.*, p. 230): "Seares has quoted the foregoing figures as giving the definitive scale corrections to the magnitudes of the two catalogues." Eberhard gives, not scale corrections to the catalogues, but only the difference between the two scales. Moreover, these differences were not included in the *Report* as definitive values. My statement was only a summary of Eberhard's results, printed without comment. The important systematic error in R.A. revealed by Eberhard's comparison shows that a much more extended investigation will be required to establish the definitive relation between Y and Y_2.

Y and Gr.—Here again I think that Holm has overestimated the mean errors, that for Gr being of especial importance in this case, since the differences are grouped according to Gr. The average deviation from the mean *Pg* system for about two hundred stars is $\pm$0.066, the corresponding mean error about $\pm$0.09, as compared with an average of $\pm$0.109 given by Holm (Table VII). The large and erratic fluctuations in the logarithmic derivatives (Table VIII), which arise from very small irregularities in the frequencies (Table V), also arouse suspicion as to the significance of some of the corrections. Because of the higher precision of Y, it would have been advantageous to have grouped the differences according to magnitudes of this catalogue.

A misprint may be noted: The color index for Ko given on p. 242 should be 1.07, not 1.02.

RECENT RESULTS

The best method of testing this matter and, incidentally, of verifying and strengthening the systematic corrections to the catalogues is to make additional observations, both photographic and photovisual, with large-field short-focus cameras. An independent determination of the magnitudes of a few hundred stars with the aid of an increased number of NPS standards will at once check the mean system and the individual systematic corrections which define it and, at the same time, greatly increase the precision of the individual magnitudes. An investigation of this kind, which promises very satisfactory results, is already well advanced. Through the kindness of Mr. W. H. Christie, who has used the 10-inch Cooke refractor (moving-plate camera) at Mount Wilson, and of Dr. F. E. Ross of the Yerkes Observatory, who has supplied measures from photographs taken with the 13-inch camera at Flagstaff and with 5- and 3-inch Ross lenses, much additional material is already available.

As a preliminary to the reduction of these photographs, the mean system itself was first slightly revised in order that the best magnitudes possible might be available as an aid in determining the distance corrections for the various cameras used. Changes of 0.01 or 0.02 mag. were made in some of the scale corrections in order to eliminate the residual systematic effects shown by Gr, S, YPv, and PD. Mainly on the basis of evidence supplied by the NPS stars, the color coefficients of the *Pg* corrections were increased by 0.05 throughout. Since this change affects the zero point, a compensatory zero-point correction was required, the total change being $-0.02 + 0.05C$. Corresponding adjustments were also made in the *Pv* color system. The revised total corrections for YPv and PD are in the second and third columns of Table I; for PDP, however, the original correction (*Report*, eq. [4]) was used. Mean magnitudes were then formed with the aid of weights based on the average deviations of the respective catalogues from the provisional mean system. The relation of the revised mean system to the international system was then tested by means of the camera photographs.

Owing to difficulties with the distance correction, Christie's measures (*Pg* scale) are not yet completely reduced. They indicate, however, that the adopted change in the *Pg* color system was justified,

and, as far as they go, reveal no additional correction to the mean *Pg* system.

Ross's measures of 12 *Pv* plates—2 with the 13-inch Flagstaff camera, 2 with the Ross 5-inch lens at Mount Wilson, and 8 with the 3-inch Ross lens of the Yerkes Observatory—are completely reduced. Measures by Ross on other plates made with these instruments are already in our hands, but it is unlikely that their inclusion will modify the systematic relations, although the magnitudes of individual stars will, of course, be appreciably strengthened.

TABLE I

SYSTEMATIC CORRECTIONS TO CATALOGUES OF PHOTOVISUAL AND VISUAL MAGNITUDE

Pv	IPv−YPv	IPv−PD	IPv−PDP
5.25	+0.04+0.04*C*	−0.22+0.10*C*	.....
5.75	.08 .04	.22 .10	.....
6.25	.08 .05	.22 .10	−0.19+0.03*C*
6.75	.08 .06	.22 .10	.17 .03
7.25	.08 .06	.20 .10	.13 .03
7.75	.08 .06	.19 .09	.11 .03
8.25	+0.08+0.03	−0.17+0.06	.10 .03
8.75	.....	.....	.12 .03
9.25	.....	.....	.14 .03
9.75	.....	.....	−0.14+0.03

The reduction was made with the aid of the 26 NPS stars listed in Table II; color equations and distance corrections were determined for each instrument. Provisional comparisons indicated excellent agreement with the YPv and PD magnitudes, corrected as described above, but that PDP seemed to require an additional correction, represented approximately by +0.02 +0.06 *C*. This correction was applied, and weighted mean magnitudes were then formed by combining for each star all the values obtained from Ross's plates with those from the three catalogues. The weights for Ross's magnitudes also were derived from their respective average deviations, unit weight, as in the case of the catalogues, corresponding to an average deviation (AD) of ±0.10 mag.

The resulting magnitudes for the NPS stars and their deviations (unit = 0.01 mag.) from the international values (IPv)[8] are in the

[8] *Transactions of the International Astronomical Union*, 1, 71, 1922.

second and third columns of Table II. The residuals reveal no appreciable error either in scale or in color system. With the exception of stars 2*r* and 14, for both of which large deviations are to be expected, no difference exceeds 0.05 mag. The average deviations in the fourth column refer to a single-plate or catalogue value, the total number of which appears in the sixth column of the table. Since the magnitudes of all other stars were derived from the same reduction-curves as those of the NPS stars, the mean *Pv* magnitudes as a whole

TABLE II

MEAN PHOTOVISUAL MAGNITUDES OF NPS STARS COMPARED WITH INTERNATIONAL VALUES
(Unit = 0.01 mag.)

NPS	$\overline{Pv}$	IPv − $\overline{Pv}$	AD	Wt.	No.	NPS	$\overline{Pv}$	IPv − $\overline{Pv}$	AD	Wt.	No.
1...	4.37	0.00	±2.0	66	12	3r.	7.55	+0.02	± 5.6	44	13
2...	5.28	0	5.1	47	9	10..	9.05	+ 1	5.5	25	13
3....	5.58	− 2	3.8	66	12	4r.	8.29	− 2	3.6	40	13
4...	5.83	+ 1	3.5	65	12	11..	9.61	− 5	3.3	13	10
5...	6.43	+ 2	5.8	72	15	12..	9.82	− 5	4.0	11	8
2s...	6.30	0	5.4	71	15	5r.	8.67	− 4	4.5	33	13
3s...	6.30	+ 5	5.2	71	15	4s.	9.82	+ 1	4.0	12	8
1r...	5.06	+ 3	7.0	64	12	13..	10.37	0	7.2	10	7
6...	7.11	− 5	4.7	65	15	6r.	9.21	+ 3	4.2	21	13
7...	7.53	+ 2	2.8	51	14	14..	10.42	+ 14	11.2	10	6
2r...	6.39	− 7	5.3	72	15	7r.	9.86	+ 1	5.4	10	7
8...	8.10	+ 3	1.4	36	12	6s.	10.75	− 3	4.5	8	3
9...	8.87	−0.04	±6.1	25	13	8r.	10.46	0.00	± 4.4	9	7

should be in close agreement with the international system. The deviations of the different catalogues and groups of plates from the mean *Pv* magnitudes should therefore indicate the systematic relations of the various divisions of the data to the IPv system.

These systematic deviations (SD) are in Table III, listed separately for the YPv, PD, and PDP catalogues and for the three instruments used by Ross. The average deviations (AD) refer to a single catalogue position (based usually on several plates or on two or more visual observations) or, in the case of Ross's measures, to a value from a single plate. In forming the mean magnitudes the rejection limit was placed at four times the AD, but none of the 695 catalogue values attained this limit. Of the 1656 values by Ross, 49 were re-

TABLE III

COMPARISON OF CATALOGUES, CORRECTED FOR SYSTEMATIC ERROR, AND GROUPS OF PLATES WITH MEAN PHOTOVISUAL MAGNITUDE

(SD = $\overline{Pv}$ − *Catalogue* or *Group;* unit = 0.01 mag.)

$\overline{Pv}$	YPv				PD				PDP				Flagstaff, 13-in. (2 Pls.)*			
	SD	AD	Wt.	Stars	SD	AD	Wt.	Stars	SD	AD	Wt.	Stars	SD	AD	Wt.	Stars
4.54	−1.4	±4.6	51	8	+1.2	±6.4	36	8	.....	.....	.....	.....	.....	.....	.....	.....
5.25	−1.1	5.3	59	12	+2.3	7.3	50	12	.....	.....	.....	.....	.....	.....	.....	.....
5.75	+1.8	3.5	95	17	+0.1	3.3	81	17	−13.0	±13.0	2	1	.....	.....	.....	.....
6.25	+1.7	4.0	167	30	−0.5	3.5	138	30	− 4.0	7.7	22	7	−3.8	±7.9	14	4
6.75	+0.2	2.9	196	39	+0.7	3.8	184	39	− 6.0	8.9	58	22	+5.0	8.2	4	2
7.12	0.0	3.4	179	36	+1.4	3.4	164	36	− 1.6	7.3	76	33	+6.0	6.0	4	1
7.38	−0.4	4.4	148	31	+1.4	3.9	131	31	− 0.2	7.0	80	32	−1.6	6.1	15	5
7.62	−1.1	3.9	98	21	−0.9	3.9	86	20	+ 3.2	7.7	48	20	−2.0	5.0	10	2
7.88	−0.3	5.0	76	15	+1.2	5.2	63	15	− 0.5	7.7	48	17	−6.1	8.3	14	2
8.25	+2.0	±2.9	25	6	−3.0	±3.4	21	5	− 1.9	5.0	70	23	−2.0	3.7	162	17
8.75	.....	.....	.....	.....	.....	.....	.....	.....	− 0.7	5.7	68	22	+2.2	4.4	205	22
9.25	.....	.....	.....	.....	.....	.....	.....	.....	− 1.7	6.5	105	34	−0.2	5.2	232	33
9.75	.....	.....	.....	.....	.....	.....	.....	.....	+ 1.8	4.6	112	36	−3.3	6.6	201	36
10.25	.....	.....	.....	.....	.....	.....	.....	.....	+ 4.9	6.7	56	18	−3.3	5.8	95	18
10.75	.....	.....	.....	.....	.....	.....	.....	.....	+ 1.5	± 1.5	6	2	−1.2	±3.2	15	3
Totals	+0.2	±3.9	1094	215	+0.6	±4.0	954	213	− 0.4	± 6.5	751	267	−1.1	±5.2	971	145

* Nos. 2 F, 10 F.

TABLE III—*Continued*

$\overline{Pv}$	MW, Ross 5-In. (2 Pls.)†				Yerkes, Ross 3-In. (4 Pls.)‡				Yerkes, Ross 3-In. (4 Pls.)§				$\overline{Pv}-Pv_\lambda$		
	SD	AD	Wt.	Stars	SD	AD	Wt.	Stars	SD	AD	Wt.	Stars	SD	AD	Wt., Stars
4.54	− 4.0	±13.0	3	1	−0.4	± 1.2	31	2	+1.0	± 1.0	25	1	+7.9	±14.0	8
5.25	− 5.0	16.5	6	2	−3.4	8.2	31	2	+1.9	4.4	50	2	−1.4	8.5	10
5.75	+ 1.0	8.8	13	4	0.0	5.0	99	5	−1.4	3.9	99	4	+3.2	8.8	17
6.25	+ 1.6	8.1	28	8	−0.8	4.3	142	8	+0.1	6.0	124	5	+1.4	10.6	29
6.75	− 2.1	6.9	30	8	+0.8	5.3	144	11	+1.3	9.1	109	5	0.0	8.9	39
7.12	− 2.5	6.5	21	5	+2.5	5.5	127	8	−3.2	6.6	133	7	−1.9	7.5	34
7.38	− 1.2	6.3	49	10	+3.4	5.5	165	12	−0.6	5.5	152	10	−0.8	9.8	31
7.62	+ 1.0	4.8	31	5	+2.7	5.1	78	6	−2.1	6.3	75	6	−3.1	8.7	17
7.88	+ 0.7	3.9	36	5	+1.8	5.8	73	7	−1.2	8.5	62	6	+4.1	12.2	12
8.25	0.0	3.5	172	17	+3.2	7.0	124	18	+0.5	7.3	124	18	−0.6	6.9	20
8.75	− 0.9	5.2	171	21	+1.2	7.9	103	22	−4.0	11.6	85	21	−3.7	9.0	22
9.25	+ 0.8	5.3	135	33	+0.7	9.2	99	34	+1.0	11.6	48	19	−4.3	7.7	34
9.75	+ 9.4	9.9	31	30	+2.6	8.7	69	36	+1.7	± 6.9	2	2	+4.2	8.9	35
10.25	+11.0	±11.0	1	1	+1.3	11.2	24	18	.....	.....	.....	.....	+3.5	±12.8	15
10.75	.....	.....	.....	.....	+7.5	± 7.5	1	1	.....	.....	.....	.....	.....	.....	.....
Totals	− 0.2	± 5.2	727	150	+1.1	± 6.2	1310	190	−0.8	±6.9	1088	106	+0.1	± 9.1	323

† Plates, A, B, C; B and C inferior, their mean counted as one plate.
‡ Nos. 1002, 1084, 1085, 1087.
§ 1089, 1094, 1098, 1101.
|| Last two groups excluded in forming mean SD and AD.

jected, all with the 3-inch lens and three-fourths of them from two plates in the last division. Neither these discordances nor the increased average error for the faint stars is to be attributed to any peculiarity of the lens, but to irregular fog on the two plates and to the fact that the thermoelectric measures, as a test of what might be possible, were intentionally extended over an interval of 5 or 6 mag. without changing the diaphragm. The lower end of the reduction-curve is therefore steep and the accidental errors correspondingly increased.

As for the systematic differences in scale, there is nothing that requires serious consideration, except possibly the divergence for the brightest stars in the PDP, which has been in evidence from the beginning. For example, see the second table accompanying the foregoing letter. This divergence seems to be real, and allowance has now been made for it in the corrections for the PDP given in Table I. The few cases of systematic divergence for faint stars are associated with highly provisional results of low weight. Three of the divisions show zero-point differences of about 0.01 mag., arising for the most part probably from residual errors in the distance correction. Except for these small zero-point differences, the individual values of SD are, on the whole, just about what would be expected, on the basis of the mean AD as the accidental error in the mean magnitudes of the different groups of stars; all of which is merely another way of stating that the results represented by the different divisions of Table III are systematically accordant.

A discussion of the differences grouped according to color index reveals no appreciable systematic effect depending on color except for the PDP (Table IV). The progressive change in the systematic deviations for this catalogue shows that the supplementary correction applied to its magnitudes before the revised weighted mean magnitudes were formed (p. 148) is slightly too large. The overcorrection cannot have affected the mean system, although it has probably increased by a small amount the average deviations for the PDP shown in Table III. Here again proper allowance has been made in the adopted systematic correction given for the PDP in the last column of Table I. The residual zero-point errors shown at the bottom of Table III of course reappear in the differences given in Table IV.

With allowance for these residual errors, the average of the values of SD for all divisions of Table IV, excepting the PDP, is the same as the accidental error of one of the individual values, as may be seen by comparing the last two divisions of the table, which represent two determinations of the color equation of the same instrument (Ross 3-in.). With the minor exception of the PDP, therefore, the data derived from all the various sources have been reduced to a homogeneous system of color. That this system coincides closely with the

TABLE IV

DATA OF TABLE III REARRANGED TO SHOW ACCORDANCE IN COLOR

(SD = $\overline{Pv}$ − *Catalogue* or *Group;* unit = 0.01 mag.)

$\overline{C}$	YPv		PD		PDP		Flagstaff 13-In.		Mt. Wilson 5-In.		Yerkes 3-In.		Yerkes 3-In.	
	SD	Wt.	SD	Wt.	SD	Wt.	SD	Wt.	SD	Wt.	SD	Wt.	SD	Wt.
−0.03	−0.7	211	+0.8	172	+2.4	163	−4.1	212	−2.0	186	+0.7	70	+0.4	97
+0.13	+0.1	217	+1.2	182	+1.5	204	−0.6	317	−1.6	54	+2.3	395	−1.4	290
+0.35	+1.0	165	0.0	160	−1.8	150	+0.5	195	+0.5	168	+0.2	382	−1.6	293
+0.81	+0.6	211	+0.3	198	−3.2	130	−0.2	195	+0.2	109	+1.4	132	−0.9	122
+1.13	−1.7	112	+2.1	93	.....	.....	.....	.....	+1.2	153	+1.1	182	−1.4	150
+1.42	+1.5	178	−0.4	149	−3.3	104	−1.7	52	+0.5	25	−0.2	149	+2.3	136
Totals	+0.2	1094	+0.6	954	−0.4	751	−1.1	971	−0.2	695	+1.1	1310	−0.8	1088

international system is indicated by the fact that the differences in Table II show no appreciable dependence on color index.

There remains still the test of the consistency of the mean *Pg* and *Pv* scales which utilizes the Greenwich effective wave-lengths. These wave-lengths were calibrated separately with the color indices (C_m) derived from the magnitudes for the three intervals $Pv < 7$, 7–8, and 8–10. Since there are no certainly established differences between the three curves, the mean of all three (Table V) has provisionally been adopted. C_λ was then derived for each star from the curve and combined with C_m to form

$$C_m - C_\lambda = Pg - Pv - C_\lambda = Pv_\lambda - Pv \, .$$

Mean values of the systematic and accidental differences for $Pv - Pv_\lambda$, weighted according to the numbers of stars, appear in the lower right-hand division of Table III. There is some clustering of alge-

braic signs, but if the intervals are widened to 1 mag., most of the effect disappears. For the eight bright stars in the first group, there may well be some inconsistency. The conditions for these objects, from every standpoint, are difficult and exacting. The mean average difference of ± 0.090 mag. is very satisfactory in view of the fact that it includes all the systematic and accidental uncertainties affecting the *Pg* and *Pv* magnitudes, the Greenwich effective wave-lengths, and the calibration-curve.

Finally, there is the relation between color index and H.D. spectral types: 64 B9−A2 stars give for Ao a mean color index (C_m) of

TABLE V

GREENWICH EFFECTIVE WAVE-LENGTHS AND COLOR INDEX
(INTERNATIONAL SYSTEM)

λ	C_λ	λ	C_λ	λ	C_λ
4180	−0.32	4320	+0.46	4480	+1.08
4200	− .28	4340	.53	4500	1.17
4220	− .23	4360	.59	4520	1.28
4240	− .13	4380	.66	4530	1.35
4257	.00	4400	.74	4540	1.42
4260	+ .02	4420	.82	4550	1.51
4280	+ .21	4440	.90	4560	1.62
4300	+0.37	4460	+0.99	4570	+1.80

−0.06; 60 Ko stars give +1.03; range, 1.09. These values are well checked by the mean values of λ for 95 Ao and 163 Ko stars, 4252 and 4461, respectively, given in the introduction to the *Greenwich Effective Wave-Lengths*. The corresponding values of C_λ are −0.05 and +0.99; range, 1.04. The agreement for Ko is all that can be expected in view of the large scatter in the color indices of these stars which results from the admixture of giants and dwarfs. For Eros comparison stars reduced to the international system Ross and Zug[9] found for Ao and Ko −0.15 and +0.95, respectively, range 1.10, while from similar data obtained at Mount Wilson[10] we derived −0.14 and +0.93 (smoothed value), range 1.07. The general agreement of these ranges with those found from the present data is fur-

[9] *Astronomische Nachrichten*, **239**, 289, 1930.

[10] Seares, Sitterly, and Joyner, *Mt. Wilson Contr.*, No. 415; *Astrophysical Journal*, **72**, 311, 1930.

ther evidence of consistency of the color system of the mean *Pg* and *Pv* magnitudes with that of the international system.

The persistent negative value of the color index of Ao stars, which is confirmed by additional measures by F. E. Carr,[11] is probably real and means that the zero point of the international *Pg* scale (NPS) does not exactly satisfy the international definition. Such a possibility was recognized when this zero point was established, because of the very small number of polar stars of known spectrum and magnitude then available. The value −0.06 for Ao now found for the polar region is still slightly uncertain: the number of stars used is moderate and the zero points of the magnitudes, especially that of the $\overline{Pg}$ values, are still uncertain by 0.01 or 0.02 mag. In view of the evidence bearing on selective absorption, we must expect the value of the color index for a given spectral type to vary to some extent with the region of the sky and the magnitude, and this circumstance may be the explanation of the difference for stars of the polar region and the Eros comparison stars, which seems to be real.

In conclusion, the present status of the systematic corrections to the various catalogues may, for clarity, be restated. The *Pg* corrections remain for the present substantially as in Table IV of the *Report* (p. 148), except that $-0.02 + 0.05C$ is to be applied throughout to the tabulated values. For YPv, PD, and PDP, Table I of this paper is to be substituted for Table VIII and equation (4) of the *Report*.

CARNEGIE INSTITUTION OF WASHINGTON
MOUNT WILSON OBSERVATORY
May 1933

[11] *Astrophysical Journal*, **76**, 70, 1932. There is a suggestion of a dependence on magnitude. See also *Transactions of the International Astronomical Union*, **4**, 137, 1932. The data in the *Report* were prepared from a provisional draft of Professor Carr's article, which differed in minor details from the results as published.

NOTES

NOTE ON THE SKY BRIGHTNESSES OF TWO REGIONS OF HAGEN'S COSMIC CLOUDS

ABSTRACT

Observations with the photo-electric photometer in two regions of cosmic clouds show very weak correlation with Hagen's scale of densities.

F. Becker[1] suggests as a test region for the observation of Hagen's cosmic clouds the neighborhood of UW and V Draconis. His chart shows clouds of density II–III immediately around UW, density IV to the north and south, and density V to the east and west. The symbol V is used by J. G. Hagen[2] to denote the greatest density of obscuring nebulosity.

Another region which Hagen says is "an easy object for learning to observe non-luminous clouds"[3] is the cloud of density IV–V extending some 24′ in all directions about X Cancri.[4] H. Shapley[5] finds from the counts of stars to the fifteenth magnitude made by Lukk[6] on the Paris charts that "the stars brighter than the fifteenth magnitude seem to be distributed much more unevenly than would be expected from elementary considerations of random distribution." Investigating counts of stars up to the seventeenth magnitude in the X Cancri region, Shapley[7] finds further that "in the immediate vicinity of X Cancri there are fewer bright stars but more faint stars than in surrounding regions."

Observations were made during last winter and spring of the sky brightnesses of regions near UW Draconis and X Cancri with the

[1] *Astronomische Nachrichten*, **224**, 113, 1925.

[2] *Specola Astronomica Vaticana*, **7**, Part I, 1931.

[3] *Ibid.*, **6A**, 211, 1927.

[4] *Astronomische Nachrichten*, **225**, 383, 1925.

[5] *Harvard Circular*, No. 281, 1925.

[6] *Publications de l'Observatoire Astronomique de l'Université de Tartu* (Dorpat), **26**, No. 2, 1924.

[7] *Harvard Bulletin*, No. 834, 1926.

photo-electric photometer attached to the 40-inch refractor of the Yerkes Observatory. The area of sky whose light was allowed to fall on the cell was a circle of 220″ diameter.

Most of the observations near UW Draconis were comparisons of two regions: (1) centered 6.′8 W. and 0.′9 S. of UW and (2) centered 13.′8 E. of the same star. Ten sets of readings were obtained comparing these two, a set usually consisting of two determinations for each region. The mean of all observations on these two regions

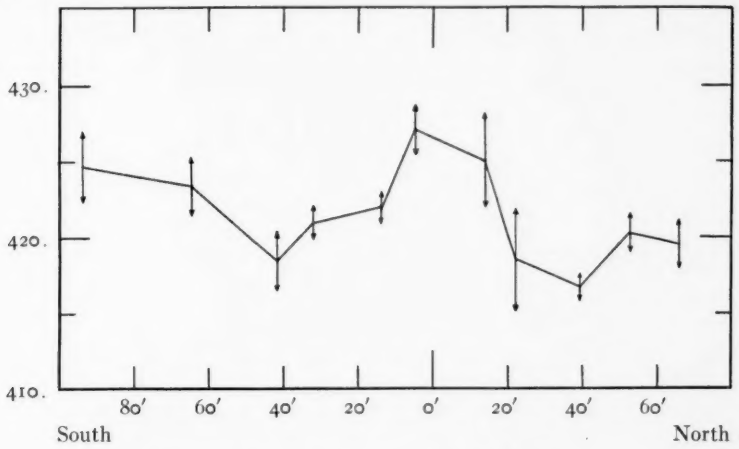


FIG. 1.—Plot of photo-electric observations of sky brightnesses north and south of X Cancri in millivolts per second per square degree.

showed region (1) to be $0^{M}.016$ brighter than region (2), with a probable error of $\pm 0^{M}.009$. Three of the four nights used were excellent for photometric observation, and the fourth slightly inferior.

Eleven regions, also 220″ in diameter, approximately on the hour circle of X Cancri, were observed as a series rather than pair by pair. This was done on each of four nights, mostly somewhat inferior to those on which the regions in Draco were observed. Each time the region just south of X Cancri was observed first, then the successive regions out to one end of the row, back all the way to the other end, and thence back to the beginning, terminating with a third observation of the region just south of the variable. These series were corrected for general change in sky brightness due to change in altitude during the series by means of the standard region,

and, also, each reading from the first three nights was reduced to the last night. The mean of all determinations for each region was taken, and the probable errors of these means computed. Figure 1 shows brightnesses expressed in millivolts charging of the electrometer per second per square degree, plotted against distance north or south of the variable star. The length of the arrow extending from each point represents the probable error.

Our measures near UW Draconis would give a slight indication that the region which Becker gave as of density II–III was slightly brighter than the region of density V. The difference, however, is very small, amounting to $0^{M}.016 \pm 0^{M}.009$, or roughly, 2 per cent with a probable error of 1 per cent. Likewise, our observations around X Cancri indicate a slight variation in brightness of sky background, but again with probable errors nearly as large as the variations.

To give an idea of what these brightnesses mean, we may cite our photometric observations on the Pleiades nebula at a position of 4′ SW. of Merope,[1] where we found the nebulosity 375 per cent as bright as the sky background. This corresponds to a difference in brightness of $1^{M}.4$.

C. T. Elvey
Paul Rudnick

Yerkes Observatory
June 29, 1933

ON THE RELATIVE INTENSITIES OF CERTAIN LINES OF *Ti* II IN THE SPECTRA OF THREE F-TYPE STARS

ABSTRACT

The relative intensities of strong and weak lines of *Ti* II are found to be quite different in the supergiant ε Aurigae than in the giants α Persei and 41 Cygni.

A year ago Struve[2] noted the abnormal relative intensities of the metallic lines in the spectrum of the peculiar A-type star 17 Leporis. When compared with the F5 supergiant ε Aurigae, the gradient of intensity of the strong and weak lines was shown to be much steeper in 17 Leporis than in ε Aurigae.

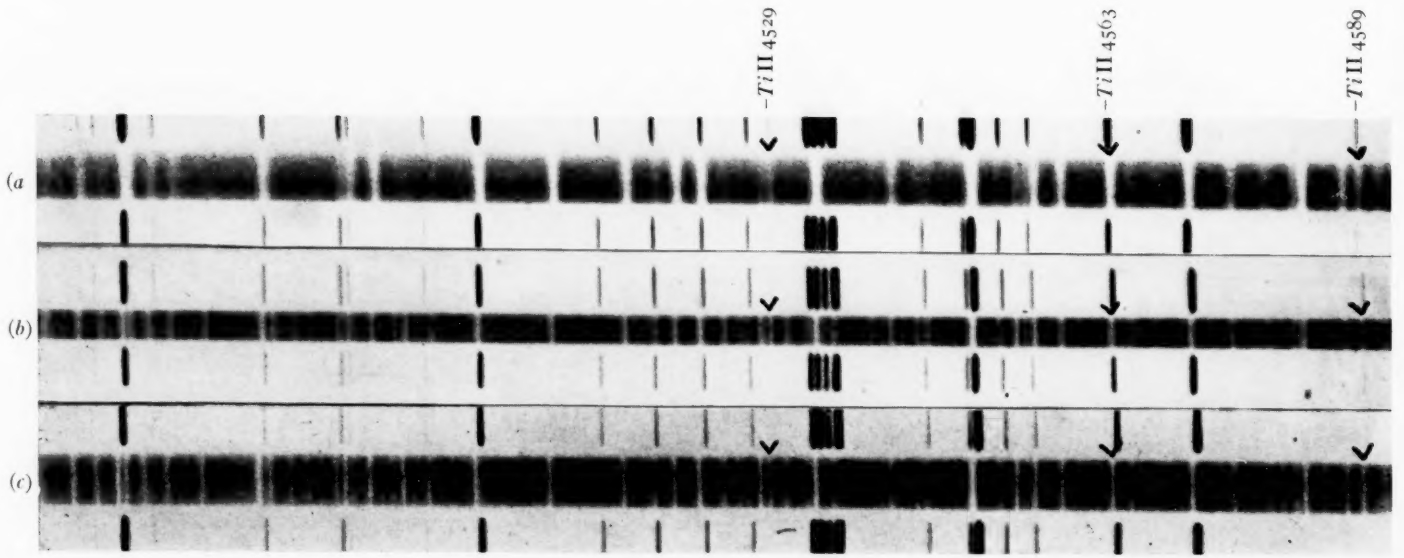
The latter star also seems to be abnormal with respect to the

[1] The region is the circle shown southwest of Merope on Pl. VIII (facing p. 280) of Vol. **77** of the *Astrophysical Journal*.

[2] *Astrophysical Journal*, **76**, 96, 1932.

UNIV. OF MICH.

PLATE VII



SPECTRA OF (*a*), ϵ AURIGAE; (*b*), α PERSEI; (*c*), 41 CYGNI

The range included is from λ4463 to λ4593. The relative intensities of the three *Ti* II lines are quite different in ϵ Aurigae than in the two other stars. The H.D. spectral types of all three stars are the same, i.e., F5.

gradient of the metallic lines when compared with the stars α Persei and 41 Cygni. This is well shown in the case of *Ti* II. The weak lines are slightly weakened or remain unchanged in ε Aurigae, while the strong lines are considerably strengthened. The three lines marked in Plate VII show the effect clearly. Table I gives the wavelengths, laboratory intensities, excitation potentials, and multiplet designations of the lines. All three are sensibly unblended. In α Per-

TABLE I

LINES OF *Ti* II

λ	Lab.	E.P.	Multiplet
4529	(1)	1.565	$a^2H_{4\frac{1}{2}} - z^2G^{\circ}_{4\frac{1}{2}}$
4563	(30)	1.216	$a^2P^{\circ}_{\frac{1}{2}} - z^2D^{\circ}_{1\frac{1}{2}}$
4589	(2)	1.232	$a^2P^{\circ}_{1\frac{1}{2}} - z^2D^{\circ}_{1\frac{1}{2}}$

sei and 41 Cygni λ 4563 is slightly but not very markedly stronger than the other two lines, while in ε Aurigae the difference in intensity between the strongest and the weakest of the lines is very marked.

The excitation potentials of the lines are not very different, and two of them belong to the same multiplet. From a consideration of other *Ti* II lines which show the effect, it seems rather certain that the change in gradient is concerned with the intensity of the lines rather than with excitation potential or multiplet structure.

A similar effect has been noted by Struve[1] for lines of *O* II in the early B-type stars.

W. W. MORGAN

YERKES OBSERVATORY
WILLIAMS BAY, WIS.
July 3, 1933

ON THE SPECTRUM OF HYDROGEN SULPHIDE

ABSTRACT

Bands appearing in the H_2S spectrum which were suggested as being due to S_2 are correctly assigned to the *CS* molecule.

In a paper published recently by the writer[2] on the spectrum of hydrogen sulphide, a group of diffuse bands extending from about 2470 A to 2860 A were tentatively assigned to sulphur.

[1] *Ibid.*, **78**, 73, 1933.

[2] *Astrophysical Journal*, **77**, 270, 1933.

Subsequently the writer has compared his plates with the published spectrograms of a band system, ascribed to *CS*, which was discovered by L. C. Martin[1] and investigated more completely by W. Jevons.[2] The bands appear to be identical and therefore should be assigned to the *CS* molecule.

The writer wishes to thank Professor A. Fowler and Dr. W. Jevons for bringing the work on the *CS* spectrum to his notice.

NORMAN O. STEIN

UNIVERSITY COLLEGE, LONDON
CHEMISTRY DEPARTMENT

[1] *Proceedings of the Royal Society*, **89**, 127, 1914.
[2] *Ibid.*, **117**, 351, 1928.

REQUEST FOR UNPUBLISHED OBSERVATIONS OF VARIABLE STARS

In a number of observatories and private libraries there are long series of observations of variable stars which have never been published. These observations are of considerable importance in the investigation of possible changes in periods and in the shapes of the light-curves. At its Cambridge meeting in 1932 the International Astronomical Union, at Professor Shapley's suggestion, voted to publish an abstract of such unpublished observations and Mr. H. Grouiller was intrusted with its preparation. Under present conditions the actual publication of the observations is impossible but an abstract could be made available at a small cost. All those who have access to unpublished observations of variable stars are requested to send me the list of stars, the dates of observation, and the method used, together with suggestions for making the observations available if they should be desired.

H. GROUILLER

OBSERVATOIRE DE LYON
ST. GENIS LAVAL (RHÔNE) FRANCE